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Individual agent decision-making and outcomes within systems facing disruptions

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Certification

I, Jonathon Mackay, declare that this thesis submitted in fulfilment of the requirements for the conferral of the degree, Doctor of Philosophy, from the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualifications at any other academic institution.

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Jonathon Mackay

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List of Publications

The following are a list of publications by the author that have emerged from works related to the thesis as of this date.

Mackay, J., Munoz, A. & Pepper, M. 2019. A disaster typology towards informing humanitarian relief supply chain design. *Journal of Humanitarian Logistics and Supply Chain Management*, doi https://doi.org/10.1108/JHLSCM-06-2018-0049

Mackay, J., Munoz, A., Pepper, M. & Ryan, E. 2019, Operationalising and evaluating redundancy and flexibility-based management strategies within a queuing system, Conference Paper, 9th IFAC CONFERENCE MIM, Berlin

Abstract

A common theme across many systems—social systems (e.g. organisations), biological systems and even sub-atomic systems—is that perturbations can negatively influence performance. Negative perturbations—or disruptions—can emerge from both endogenous and exogenous sources, depending upon the permeability of a system's boundaries.

Accordingly, there is a unique dilemma whereby open systems (with permeable boundaries) often depend upon their external environments to survive but are also subject to disruptions originating from these environments. This dilemma has given rise to research in disruption management; which is applied interdisciplinary across areas such as supply chain management, organisational behaviour and disaster management. Rather than prescribe guidance towards risk mitigation and contingency through 'ideal' strategies, the thesis aims to explore how individuals—as agents within a system—act when facing disruptions, and what is the nature of the relationship between individuals, the systems they operate in and post-disruption system behaviour.

The thesis explores two main theoretical realms to understand this phenomenon; systems theories and decision-making theories. Systems theories have their origins in General Systems Theory (GST) (Von Bertalanffy 1938) as a means of investigating phenomena holistically—where—to paraphrase Aristotle—the whole

is greater than the sum of the parts. System theories argue that systems possess a mix of characteristics—such as the ability to engage with exogenous environments, goal-seeking behaviour and non-linearity—that influence how systems behave under a variety of circumstances. Social systems—those that are governed by the actions of human actors—are the focus of this thesis.

The second stream of literature explores decision-making theories associated with decision-making under uncertainty. When operating under uncertainty, individual and systemic characteristics influence the ability of an individual to act rationally. The main decision theory used within the thesis, Protection Motivation Theory, espouses that the decision to mitigate against a disruption is subject to a dual appraisal process of both a threat (i.e. threat appraisal) and the ability to respond to it (i.e. coping appraisal).

A gap exists in the intersection between the two theories, which motivates the following aims of the thesis:

(1) To explore individual decision-making across a wide variety of contexts (i.e. individual roles, disruption types, system types);
(2) To understand how individual appraisals of disruptions influence their agency and choice, and;
(3) To enhance extant understanding of the interrelationship between disruptions, choice and system behaviour.

The thesis is exploratory, utilising qualitative research methods. Semi-structured interviews, using the Critical Incident Technique (CIT), have been used to elicit individual experiences of past disruptions in order to capture both decision-making and system interactions. The thesis applies an abductive form of logic; whereby individual experiences are analysed according to both extant (i.e. from the literature) and emergent (i.e. from interviews) themes.

The thesis utilised semi-structured interviews to ascertain 29 unique disruption data points with individuals across a wide range of contexts. These contexts varied significant across the 16 interviews undertaken, with a primary focus on organisations. Through conducting interviews with individuals across a wide range of spectrums (rather than system or disruption specific), a holistic investigation of the interrelationship between decision-making protocols and system behaviour can be undertaken. Although this method comes with a trade-off—particularly with quantitative approaches common within both literature streams—the exploratory nature of the thesis has led towards unique insights and emerging themes that contribute to the ongoing discussion surrounding individual decision-making within systems facing disruptions.

The results demonstrate that there is an intrinsic—and multifaceted—relationship between the individual and their respective system. Expanding on the idea of a triadic relationship between the individual, system and disruption (Scheibe & Blackhurst 2017), the results indicate that system behaviour is contextualised as

disruptions can manifest themselves from various sources. The behaviour of systems—and the individuals within them—is dependent upon individual framing with respect to the relationship between a focal system (i.e. that an individual is directly part of) and other subsystems and suprasystems. The results indicate that individual choices can be expressed according to their temporal scope (proactive/reactive), as a redundancy/flexibility and the rapidity of which choice is enacted into action (fast/slow). Furthermore, the results suggest that systems will behave in a limited number of ways post-disruption, reflecting the role of choice and systemic factors in determining post-disruption system outcome.

The thesis has several implications for both theory and practise. By employing a qualitative approach to the research problem, the thesis presents findings regarding the interplay between decision-making and post-disruption system behaviour. These findings demonstrate the need to analysis individual decision-making in a holistic manner with regards to triadic intersections between the individual, system and disruption.

The theoretical contributions can be divided into both system and decision theory implications. First, the thesis contributes to the literature by evaluating how individuals make decisions within systems facing disruptions and by exploring the intersection between choice and systemic influences. By exploring the link between these two separate areas of academic discourse, the thesis provides a greater

theoretical understanding of the holistic relationship between an individual, a disruption and the relevant system.

In terms of practical contributions, the results provide several models that serve as guidance towards understanding both choice types and the factors that may influence system performance post-disruption. Resultant from the wide array of contexts within the data collected, the thesis provides frameworks that are applicable towards practitioners in a wide setting both within organisational systems and other systems.

It is entirely probable that social systems are inherently chaotic, and often drift between various basins of attractions of order and disorder. Although a shift of system behaviour into chaotic oscillations does not guarantee failure—and may indeed lead to new positive states of existence—the perpetual existence of disruptions suggests that need for individuals to be simultaneously proactively preparing, and reactive acting, to deal with the consequences and to ensure system viability. This thesis contributes to these concurrent discussions by arguing that a holistic representation of individuals, systems and disruptions is needed in order to effectively understand how individual decision-making within systems facing disruptions is undertaken.

Acknowledgments

When I first chose to undertake my doctorate thesis, I was a young (mid-20s) knowledge-hungry scholar ready to explore how the world works, or most importantly how it on occasion *doesn't* work. Now at the end of the road I'm an old scholar (late-20s), but I have been able to shape that hunger for knowledge into a large variety of different endeavours, most notably of course is this thesis.

I would first like to acknowledge my supervisors, Dr. Matt Pepper and Dr. Albert Munoz, for their continued support and encouragement over the course of the past 3-and-a-bit years. Having had the fortune of being lectured by them both in my undergraduate years, they were both very keen to take me on firstly through honours and now through the PhD experience. I'm grateful for their consistent guidance and patience, even if I was asked weekly for 3 years as to whether I had already finished. The pursuit of knowledge works better in teams, and for that I'm grateful to have been able to work with both Matt and Albert over the course of the past few years.

Secondly it is quite a daunting—and sometimes lonely—experience doing a doctoral thesis. In between deadlines, late nights and academic imposter syndrome, the toll can be quite heavy at times. Therefore, I would like to acknowledge two of my peers, Messrs James Borthwick and Sebastian Isbanner for their friendship and peer support over the past three years. From our lunchtime debates about how to fix

the world's problem, to just a cup of coffee and a chat when the thesis experience is overwhelming, the friendship has helped me get through this process.

Finally, I would like to acknowledge my friends and family for their continued support over the past three years. In particular I would like to acknowledge my parents, Stephen and Allyson Mackay, for always being a caring and encouraging light in my life; particularly when it comes to crazy ideas (such as deciding to pursue my PhD), not to mention allowing me to (still!) live at home during this period.

Tables and Figures

Glossary[1]

Adaption: the process where an element changes itself to fit within its environment (Holland 1995).

Agency: the intention and capability to undertake a particular action (Giddens 1984).

Basin of Attraction: a region in state space in which a system tends to remain (Walker et al. 2004).

Chaos: a type of system behaviour whereby seemingly random behaviour can be explained as insensitivity to initial conditions (Kauffman 1991). Chaotic systems are predictable in pattern but not in trajectory (Schneider & Somers 2006).

Choice: the particular path undertaken by an individual within a certain set of circumstances (Fishburn 1981).

Complexity: the degree to which higher levels patterns and macroscopic properties of a system emerge from localised interactions amongst components (Levin 1998).

Complex System: a type of system dictated by diversity and individuality amongst components, non-linear behaviour and adaption (Levin 2003).

[1] For the most part direct quotes have been used from the literature for the definitions. However, a number of definitions have been paraphrased for clarity where appropriate.

Critical Incident: any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act (Flanagan 1954).

Disaster: a high-magnitude disruption whereby system capabilities are overwhelmed, and external assistance is needed for the system to return to an acceptable level of performance (Mackay et al. 2019).

Disruption: An event (or series of events) that impact the ability of a system to maintain performance levels.

Edge of Chaos: a system state whereby conflicting forces of order and disorder shift a system towards an uneasy equilibrium between these two contrasting forces (Skufca et al. 2006).

Efficacy: the belief that an actor can successfully undertake a particular action within a given situation (Bachrach & Zautra 1985; Bandura 1977).

Endogenous Environment: environment that exists within a system's boundaries. *See system boundaries.*

Exogenous Environment: the environment that exists outside of a system's boundaries.

Holism: the idea that a system can only be explained as a totality; greater than the sum of its parts (Kast & Rosenzweig 1972).

General Systems Theory: a theoretical approach to understanding phenomena based upon the interaction and emergence of various sub-system components (Von Bertalanffy 1972). In contrast to *reductionism.*

Nonlinearity: a system behaviour where effect is not solely explained by cause (Sterman 2000). A common feature in dynamic, 'real-world' systems (Forrester 1987).

Performance: the efficiency and/or effectiveness of a system to achieve specific goals (adapted from Beamon 1998).

Perturbation: small differences effect in the actual state of the system (Jen 2003).

Reductionism: a traditional approach towards understanding phenomena based on the decomposition into individual components (Ackoff 1973).

Resilience: the ability to recover within acceptable timeframes and losses (Aven 2011; Haimes 2009).

Robustness: insensitivity to the disruptions influence on performance (Haimes 1998).

Social System: a subclass of systems defined by the activities of human actors (Whittington 1992).

Stability: persistence of a system near or close to an equilibrium state (Holling 1973).

Strategy: a priori guidelines or evolved, posteriori consistencies in decisional behaviour (Mintzberg 1978).

Sub-System: the interrelated parts and elements of a system (Kast & Rosenzweig 1972). Also called *components* or *elements.*

Supra-System: the larger system of which systems are part of, dependent upon the system boundaries (Kast & Rosenzweig 1972).

System: any entity that possesses one or more interrelated component, or *subsystem* (Kast & Rosenzweig 1972).

System Boundaries: abstract, semi-permeable (for open systems) perimeters of a system that define the components that make up the system (Whitney et al. 2015).

Threat: the capability of an individual or event to adversely affect a system by changing its states (Haimes 2006).

Transient Response: the time-series generated during and after a disruption (Melnyk et al. 2014).

Vulnerability: manifestation of existing system states that can be exploited to further harm a system (Haimes 2006).

Chapter 1 Introduction

1.1 Background to the Thesis

In his paper reflecting on the lessons learnt from Hurricane Katrina that had battered New Orleans in 2005, Ali Farazmand (2007, p. 157) made the following insight:

> A key characteristic of all chaos and dynamic crisis situations — such as spontaneous revolutions, Katrina-type crises, and the like — is the presence of a high number of inconceivables [sic] and unexpecteds [sic] that surprise everyone. All officials and organizational actors were totally caught by surprise — surprise that paralyzed the entire response system and produced more chaos and further surprises, triggering disaster after disaster. This could have been avoided had there been capacity building for "chaos and surprise management" in advance. We simply cannot manage chaos with routine administration and governance.

The above quote—whilst referring to an extreme event such as Hurricane Katrina—can be interpreted as an alarmist response or 'spring-into-action' response towards managing disruptive behaviours within systems. Although Hurricane Katrina itself fell into a 'perfect storm' type of event; combining a relatively low perception of occurrence and a high magnitude of consequence; the quote suggests the existence of behaviours permeated by both system contextual components and the individuals within those systems. As the quote refers to Hurricane Katrina as a type of chaotic behaviour, this behaviour can also encapsulate a wide range of magnitudes in terms of disruptions. Additionally, the final line of the above quote suggests that chaos can

be managed given the right set of circumstances; suggesting that individuals within a system do possess the agency to influence system behaviour. This is the primary point that the thesis wishes to address; harnessing further understanding of how individual actions can guide systems towards a point of recovery during chaotic disruptions. Addressing this point has implications across the spectrum from disruptions emergent from routine, everyday behaviours (for example work-based demand disruptions) to more extreme humanitarian disasters (which fall outside the scope of the data obtained within this thesis).

Systems are broadly defined as any phenomena composed of inter-relating parts with varying degrees of complexity (Boulding 1956; Buckley 1967; Kast & Rosenzweig 1972). These varying degrees of complexity follow a hierarchy ranging from static structures to social organisations (Boulding 1956).

The system type central towards the thesis is are social systems; systems that are dominated by human actors (Whittington 1992). Within these systems, individual actors can be expressed as possessing degrees of agency, encompassing both the intention and capability to undertake a particular action (Giddens 1984). Individuals within these systems can play a critical role in propagating disruptive behaviours or mitigating the impact of an event. Certain events—true for both catastrophic disasters such as hurricanes and a wider range of disruptions—trigger a need for human intervention outside of routine practises.

These events, so-called *disruptions*[2] are contextual as they can manifest into a variety of different forms with various outcomes. Extant literature explores the intersection between disruptions and systems across a variety of scenarios, including stochastic uncertainty in operations (Flynn et al. 2016), high-magnitude events such as disasters (Day et al. 2012; Mackay et al. 2019) and predominantly human-driven disruptions such as terrorist attacks (Haimes 2011). The impacts too can vary, ranging from seemingly minor variations in system behaviours (e.g. minor stochasticity in demand rates) to widespread system (or sub-system) failure (e.g. an organisation collapsing).

One way to understand how individuals act when facing disruptions is with decision-making models. Decision-making models are often linked to utility theory (Bernoulli 1738; Edwards 1954), whereby an individual will choose a particular action that leads to the highest satisfaction (Bernoulli 1738). Addressing situations when events and outcomes are uncertain, a number of scholars (such as Kahneman & Tversky 1979; Slovic 1987; Tversky et al. 1982) discuss the idea of decision-making under uncertainty. These theories are driven by the premise that individual appraisals are impacted by bounded rationality (Simon 1959), and thus information about certain events may be difficult to ascertain. The main decision-making under uncertainty model adopted within the thesis is Protection Motivation Theory (PMT),

[2] The thesis adopts the term *disruption* due to its applicability to a vast array of scenarios. The term (and other relevant synonyms) are defined in the Glossary, page ix.

which argues that an individual will adopt a choice to protect themselves based upon their appraisal of the disruption and their ability to act towards mitigation (Rogers 1975; Rogers 1983).

The premise that drives this thesis is that decision-making—when conducted effectively—can improve the ability of systems to withstand disruptions. Accordingly, the thesis will seek to explore the factors that influence decision-making and what determines the effectiveness of a given strategy to either prevent, withstand or recover from the impact caused by disruptions. This intersection between individual choice and system behaviour is crucial towards enhancing knowledge of disruption management as they provide a unique insight into how individuals engage with systems they operate within.

1.2 Research Objectives and Questions

The thesis aims to ascertain a more holistic perspective of decision-making under uncertainty through a system lens. This holistic perspective is guided by three main aims:

(4) To explore individual decision-making across a wide variety of contexts (i.e. individual roles, disruption types, system types);

(5) To understand how individual appraisals of disruptions influence their agency and choice, and;

(6) To enhance extant understanding of the interrelationship between disruptions, choice and system behaviour.

In order to achieve these aims, the thesis will seek to answer several questions. These questions are reflective of the three main focal points of interest to the thesis; disruptions, decision-making under uncertainty and systems. The first series of questions are reflective of the disruption:

(1) How do disruptions manifest themselves within social systems?

(2) What are the main characteristics of disruptions?

The second series of questions are associated with individuals making decisions within systems facing disruptions:

(3) What are the antecedent and systemic circumstances that influence an individual's choice to make decisions when facing disruptions?

(4) How do systemic factors influence an individual's agency to make decisions?

(5) What are the main dimensions of choice types?

The third series of questions relate to the holistic interaction between disruptions, individuals and systems:

(6) What is the interaction between these choices (or lack of choices) and the system in which they operate?

(7) How do disruptions manifest themselves within system behaviour?

The thesis aims to explore the nature of how individual choices are made through an exploration of individual experiences. Accordingly, semi-structured interviews

based on the Critical Incident Technique (Flanagan 1954) are conducted to further understand how individuals make decisions within systems facing disruptions.

1.3 Justification of the Study

The study of systems and decision-making under uncertainty are important areas of the literature in their own realm. The issue of effectively guiding systems through periods of uncertainty has received considerable interest within the operations and supply-chain management literature, and decision-making under uncertainty has been at the forefront of research within the behavioural psychology literature for several decades. Accordingly, the thesis provides an important opportunity to further enhance knowledge of how individuals make decisions within systems facing disruptions.

1.4 Delimitation of Scope

The focus of the thesis is social systems; whereby individuals possess degrees of agency. Although non-social systems (e.g. biological and mechanical) are explored within the literature review, the semi-structured interviews focus solely on human-orientated systems. In terms of system boundaries, the thesis seeks to explore the intersection between agent-driven strategies and system behaviour across a large array of different systems, seeking to enhance the interdisciplinary value of the results.

Although the thesis seeks to explore system behaviour from the lens of decision-making rationale, the psychological factors that inform choice fall outside the scope of the research. Consequently, the thesis assumes that individuals possess significant heterogeneity amongst the psychological factors that influence the adoption of certain behaviours. Although several common behaviours are discussed when exploring decision-making theories in Chapter 2 (such as individual propensity to frame losses greater than gains), the aims of the thesis are primarily to understand the interaction of individual choices within system behaviours impacted by disruptions.

1.5 Contributions of the Research

The main contribution of the thesis lies in its universality, as exploring disruptions and decision-making across a wide variety of contexts and scenarios allows for the results to be applied holistically. By focusing on a vast array of individual experiences—rather than focus on a system or disruption *type*—the thesis provides substantial contribution to the theoretical understanding of decision-making within systems facing disruptions.

From a methodology perspective the research contributes to the ongoing discussion surrounding decision-making under uncertainty. Namely, the thesis uses semi-structured interviews as a mechanism towards gathering a holistic approach towards how individuals make decisions under uncertainty by allowing the individuals to explore their experiences of disruptions in real-time. This

differentiates itself from other research methods (e.g. surveys) that would not have provided the same richness for emergent themes that was ascertained from the semi-structured interviews.

From a practical perspective, as the quote at the start of the chapter suggests; greater understanding of actions that guide disruption recovery can lead to a wide array of benefits. At the extreme end, these may include lives (as the wider humanitarian literature demonstrates) but also general performance outcomes for other systems. By providing a greater number of tools to assist individuals understand the world around them—explained as a triadic reaction between individuals, systems and disruptions—the thesis can be used to inform more effective decision-making.

1.6 Thesis Overview

The thesis is constructed in the following manner. Chapter 2 reviews the literature pertinent to this thesis. The chapter is split into two parts, looking at systems theories and decision-making theories respectively. The chapter starts by exploring the history of General Systems Theory, issues surrounding the role of non-linear behaviour and an overview of risk-based systems theories. The second half of Chapter 2 reviews key decision-making theories. Utility theory forms the basis of many extant decision-making models, however issues with rationality lead to a schism with countless models offered to explain behaviour under specific circumstances. For decision-making under uncertainty, several key theories are

discussed, notably Protection Motivation Theory, that serves as the predominant decision theory utilised within the thesis.

Chapter 3 outlines the methodology of the thesis, namely a qualitative study using semi-structured interviews based on the Critical Incident Technique. The first section of the chapter looks at the key ontological assumptions that inform the methodological and research method considerations used within the thesis. The Critical Incident Technique is explored as a means of providing greater rigour with semi-structured interviews. Issues surrounding transcription and data interpretation are also discussed within this chapter.

Chapter 4 presents an overview of the interview process, notably the type and manner of systems explored. Throughout this chapter, a brief commentary surrounding the abductive process (and coding) are discussed. The second half of this chapter analyses the data in detail, utilising the abductive approach discussed in Chapter 4 to present both the extant and emergent themes.

Chapter 5 provides a discussion surrounding the major themes of the thesis. Firstly, a brief discussing on typology and theory development is provided as an antecedent into the discussion of the main ideas resultant from the interviews. Namely, the ideas involve a disruption profile framework, a model of disruption mitigation choices and a discussion of system behavioural types.

Chapter 6 concludes the thesis, highlighting the key findings from the previous chapters and outlining the key contributions of the thesis. These

contributions are discussed across theoretical, methodological and practical implications.

Chapter 2 Literature Review

This chapter is split into two sections reflecting the literature on systems and decision theories respectively. The chapter has been organised in this way in order to present two seemingly separate areas of academic literature before arguing the need to explore the intersection between these two theoretical areas.

First, a brief overview of the historical literature leading to the emergence of an abstract theory of systems—aptly named General Systems Theory—is discussed. As this theory provides abstract generalisations of system behaviour that led to the interdisciplinary schism of systems analysis to a wide field, several extensions of this model are discussed. Of interest to the thesis are several axiomatic system characteristics; namely openness, goal-seeking behaviour, system viability, complexity, non-linearity and agency.

The next section of this chapter discusses nonlinearity and system behaviour under risk. Conceptualising risk as a product of non-linear behaviour, uncertainty and disruptions are discussed as two avenues of explaining variance in system behaviours. The transient response—encapsulating pre and post-event system behaviour—is discussed, with an emphasis on the edge of chaos, or the central point a system can possess between conflicting states of stability and instability. The final section of the literature review on systems theories discusses two key states of

system transient response; *robustness* and *resilience*, viewing these two terms across several disciplines.

The second half of the chapter reviews the pertinent literature on decision-making theories. The structure of this latter half of the chapter is focused around several decision theories, providing an overarching narrative of how the predominant theory used within this thesis—protection motivation theory—has been developed.

Modern decision-making theories are founded on numerous works discussing how humans make decisions, centred on the tendencies to evaluate information and expectations of future outcomes as important components towards understanding decision-making theories. Therefore, this chapter begins with a discussion of the seminal works on this area. Although most modern decision-theories are linked back to the ideas of utility theory—primarily that an individual will act to maximise value—numerous amendments and changes, resulting in an abundance of theories, notably the idea that individual rationality is restricted by cognitive and environmental factors. Of primary interest towards the thesis are decision-theories associated with choices made under uncertain circumstances that can constitute a loss, referred to as risky events. Accordingly, the literature associated with risk perceptions and individual appraisals are discussed, drawing from seminal works in both behavioural economics and psychology literature. The predominant decision theory discussed is Protection Motivation Theory that stipulates individuals make choice

based upon an appraisal of both a disruption's probability and magnitude profile, but also an appraisal of their ability to act.

The chapter finishes with a synthesis of the two main streams of literature review. The argument is made that a synthesis of the factors surrounding systems theories and PMT offers a unique insight into explaining the interplay between choice and systems facing disruptions.

2.1 Defining 'Systems'

Systems are a universal construction that are widely manifested in the world. A system can be broadly defined as any entity that possesses one or more interrelated component (Kast & Rosenzweig 1972), with these components having either direct or indirect relationships with other system components (Ackoff 1971). Any system is subject to boundaries (Sterman 2000) that delineate a system from their subsystems and suprasystems respectively (Kast & Rosenzweig 1972), leading to the phrase 'system of systems' coined by Ackoff (1971).

Prior to the emergence of 20th works on systems, progresses in the Scientific Revolution saw the dominance of causal, mathematical approaches to understanding phenomena (Von Bertalanffy 1972). This positivist discourse—emphasising experimental, hypothesis-driven research approaches (Guba & Lincoln 1994) led to the dominance of theories that Von Bertalanffy (1950a) refers to as *mathematical hypothetico-deductive systems;* strict, mechanistic approaches based on exact laws of physics and chemistry that still serve as important and popular

research paradigms today. The mechanistic, or reductionist, approach—stipulating that understanding of a phenomena can be derived from decomposing it into indivisible components (Ackoff 1973)—dominated much of the discourse of research prior and during this period.

2.1.1 General Systems Theory

One of the identifiable catalysts for modern understanding of systems—and the deviation away from deductive models—are the works by Austrian biologist Ludwig von Bertalanffy. Von Bertalanffy's (1938) idea of a holistic *General Systems Theory*—an interdisciplinary approach towards systems analysis—emerged out of a scientific debate between mechanistic and organismic models (Kast & Rosenzweig 1972). Rejecting the idea of a reductionist solution to system behaviour (Van der Pijl 2009), Von Bertalanffy (1938, pp. 180-181) argued:

> In its present state, developmental physiology cannot avoid the use of specific biological concepts. We have also seen that the chemical and physico-chemical theories, Goldschmidt's theory, crystal analogy, Gestalt theory, cannot yield a complete explanation of development. There remains, therefore, for the present state of investigation at least, only one possibility: that of' an 'organismic' theory, using specific biological concepts.

GST was aimed towards synthesising several philosophical arguments into a unified model (Kast & Rosenzweig 1972). Accordingly, Von Bertalanffy (1950a, p. 4) argued that a unified model possessed common, identical isomorphic laws derived from different fields:

> There exists therefore general system laws which apply to any system of a certain type, irrespective of the particular properties of the system or the elements involved.

In applying the systems laws, the ideas proposed by von Bertalanffy emphasised a distinction between abstract generalizable constructions and discipline-specific reductionism (Boulding 1956). Therefore, its abstract origins allowed its transcendence into a variety of discipline-specific theories (Skyttner 2005), such as biology, organisational science and supply chain management. Indeed, the intrinsic value of GST exists in its ability to be applied across a wide array of disciplines (Von Bertalanffy 1950a):

> Its (GSTs) position is similar to that, for example, of probability theory, which is in itself a formal mathematical doctrine but which can be applied to very different fields, such as thermodynamics, biological and medical experimentation, genetics, life insurance statistics etc.

This abstraction is pertinent to the thesis as it suggests the ability to apply GST ideals across an arguably infinite array of systems. Although the above statement (and indeed much of the works by Von Bertalanffy) may appear abstract, several expansions offer components that can be viewed contextually across all systems.

2.2 System Components

Expansions of von Bertalanffy's original works on GST have aimed to propose a number of generalisable components that all systems will possess. Accordingly,

Table 2.1 and Table 2.2 propose two attempts to delineate systems by Kast and Rosenzweig (1972) and Adams et al. (2014); Whitney et al. (2015) respectively.

Characteristic	Description
Sub-systems or components	A system is the interaction between various sub-components.
Holism	Systems are holistic, meaning that the behaviour as a whole is greater than the sum of the parts.
Open versus Closed Systems	Systems can be characterised as open or closed based on their ability to engage with their exogenous environment.
Input-Transformation-Output	Open systems receive inputs from their exogenous environment and undergo a transformation process, which leads to outputs.
System Boundaries	All systems can be defined according to permeable or impermeable.
Negative Entropy	Closed systems, by nature of the 2nd law of thermodynamics, will naturally drift towards entropy and thus failure. In contrast, open systems are able to avoid this via their ability to import materials.
Steady state versus dynamic equilibrium	Open system can maintain dynamic equilibria through material importation. In contrast, closed systems will eventually reach a state with maximum entropy.
Feedback	Systems maintain a steady state through information regarding outputs being re-introduced into the system as feedback.
Hierarchy	Systems can be explained according to a hierarchy, with sub-systems and supra-systems developed a level of order with a system.
Internal Elaboration	Rather than moving towards maximum entropy, open systems move towards greater differentiation and elaboration.
Multiple Goal-Seeking	Systems are goal-seeking by nature, and more complex systems may possess multiple goal-seeking criteria.

Equifinality	Open systems display equifinality, whereby they are able to reach their desired goal through a various of different paths.

Table 2.1 Characteristics of GST (adapted from Kast and Rosenzweig 1972, p. 450)

In a further iteration of the characteristics identified in Table 2.1, Adams et al. (2014) (with a further adaptation by Whitney et al. 2015) proposes a series of axioms that are central to all systems. The purpose of these works was to address an identified inconsistency surrounding the definition of systems theory (Adams et al. 2014). Serving to demonstrate the characteristics that all systems possess (Adams et al. 2014, p. 112), Table 2.2 lists the axioms discussed by Adams et al. (2014) and Whitney et al. (2015).

Axiom	**Description**
Centrality	Central to all systems are (1) a hierarchy and demarcation of levels based on sub-level emergence, and (2) system control based on feedback through information.
Contextual	System meanings are determined by circumstances and surroundings.
Design	Design is purposeful imbalance of resources and relationships due to scarcity.
Goal	Specific goals are achieved through purposeful behaviour.
Information	Systems create, possess, transfer and modify information.
Operational	Systems must be addressed in situ.
Viability	Key parameters in a system must be controlled to ensure viability.

Table 2.2 Axioms of Systems (adapted from Adams et al. 2014, pp. 116-119, Whitney et al. 2015, pp. 23-24)

The characteristics discussed in both Table 2.1 and Table 2.2 offer a holistic perspective of the unifying traits across systems that are inherently contextual. As highlighted in Table 2.2, circumstances and surroundings influence the context in which a system exists and operates; this suggests that the behaviours displayed by one system cannot be treated as a universally held reality.

2.2.1 Closed and Open Systems

A fundamental characteristic of systems—as discussed in Table 2.1 and Table 2.2—is the classification of a system as existing on an open or closed continuum. This continuum is determined based upon the permeability (or penetrability) of a system's boundaries to exogenous forces (Kast & Rosenzweig 1972); whether these forces are willingly (e.g. materials, information) or unwillingly (e.g. disruptions) imported.

A closed system has no exogenous environment and is thus self-contained (Ackoff 1971). Closed systems act according to the 2nd law of thermodynamics; where they will eventually reach a state of time-independent, maximum entropy and thus eventual failure (Von Bertalanffy 1950a, 1950b). The behaviour of such systems is often determined by feedback loops (Forrester 1994) as the elements within such systems only interact with each other (Ackoff 1971). The feedback generated within a closed systems is due to these variables being opposing, and thus allowing for an equilibrium to be maintained (Whitney et al. 2015).

The definitions of closed systems and the nature of their permeability varies across disciplines. Within the System Dynamics literature, a closed system may still receive exogenous inputs, but the behaviour of interest is within the defined system (Forrester 1994). Closed systems within physics are often described in terms of reversible and irreversible processes (Resnick & Halliday 1966). This irreversibility—espoused by the 2nd law of thermodynamics—thus renders energy unable to be extracted from these systems; a novel example of this within the physics literature is a black hole (Deutsch 1991).

A large number of systems will possess some form of permeable boundaries. Boulding (1956, p. 203) describes opens systems as "the level at which life begins to differentiate itself from non-life". More specifically, a system can be classified as open based on the ability to engage with its exogenous environment (Von Bertalanffy 1950b). This engagement is often expressed in terms of material or energy importation.

Importing materials allows systems to maintain themselves given their interactions with their exogenous environment (Von Bertalanffy 1950b, 1972), Materials imported can be categorised as either energy or information (Buckley 1967, p. 47):

> Though "information" is dependent on some physical base or energy flow, the energy component is entirely subordinate to the particular form or structure of variations that the physical base or flow may manifest.
>
> …"Information" is not a substance or concrete entity but rather a relationship between sets or ensembles of structured variety.

Importation from exogenous sources assists in the long-term survival of open systems (Schneider & Somers 2006), open systems are able to reach a steady equilibrium through this exogenous interaction (Pruyt 2013). Inversely, this may result in open systems becoming dependent upon their exogenous sources to maintain system viability (Buckley 1967; Skyttner 2005). Discussing this exogenous dependence, Buckley (1967, p. 50) argues that material importation is "an essential factor underlying the system's viability, its reproductive ability or continuity, and its ability to change". This interactive relationship often refers to the input (or importation) of materials to allows systems to become *negentropic* (Buckley 1967; Kast & Rosenzweig 1972), or avoiding the natural shift towards entropy. The ability to import materials allows systems to maintain themselves due to the existence of in-flow and out-flow of materials (Von Bertalanffy 1950a, 1950b).

2.2.2 System Boundaries

As outlined within Table 2.1, systems are subject to both boundaries and hierarchies with other systems. Von Bertalanffy (1972) argues that boundaries are dynamic rather than purely spatial, therefore phenomena such as systems can only be defined by the interaction of various components.

Similarly within the organisation science literature, although boundaries can be defined as a "line of demarcation between one system and another" (Leifer & Delbecq 1978, p. 41) these particular lines may only be visible given a specific context(Aldrich & Herker 1977). Furthermore, Schotter et al. (2017) argues that the lines of demarcation can also exist within a system such as an organisation, based on both tangible sub-unit structures and nontangible ideas such as demographics and cultures.

2.2.3 System Complexity

Another perspective on systems is their ability to be expressed according to levels that determine their degree of complexity (Boulding 1956; Buckley 1967). Complexity itself can be expressed as the degree of interactions within a given system (Simon 1991), based on what Boulding (1956, p. 202) defines as a "hierarchy of complexity", ranging from static frameworks, to socio-cultural systems. Although a pitfall of Boulding's hierarchy is the lack of a thoroughly defined idea of complexity (Mingers 1997), the levels in Table 2.3 provides a visual representation of the degrees of complexity and their respective characteristics.

Level	Characteristics
Transcendental Systems	Inescapable unknowables
Socio-cultural systems	Roles, communication, values
Humans	Self-consciousness, knowledge, language
Animals	Nervous system, self-awareness
Genetic-societal systems	Society of cells, functional parts
Open Systems	Structurally self-maintaining
Control mechanisms	Closed-loop control
Clockworks	Predetermined motion
Structures and Frameworks	Static, spatial pattern

Table 2.3 Boulding's Levels of Complexity (adapted from Boulding 1956, Mingers 1997)

The interaction of humans and society—the second last level of hierarchy—encapsulates the complexity of human life (Boulding 1956, p. 205):

> The unit of such systems is not perhaps the person-the individual human as such-but the "role"-that part of the person which is concerned with the organization or situation in question, and it is tempting to define social organizations, or almost any social system, as a set of roles tied together with channels of communication.

The basis of these arguments is that 'human', or sociocultural levels possess more interrelated components that may render the system more unstable than systems with a limited number of components (Buckley 1967). An explanation for this increase in complexity is the emergence of multi-goal seeking behaviour by

individual sub-units of a system (Kast & Rosenzweig 1972), such as individuals with different tasks within one large organisation or business unit.

Therefore, social systems (discussed further in section 2.24) can be expressed as consisting of multi-goal seeking behaviours depending upon their context; an organisation will have stated goals, whereas less strictly defined systems such as a community may not have tangible, obvious goals. The final level of complexity is that of the transcendental system—reflecting ontological questions of existence (Boulding 1956)—thus lending itself to inquiries outside the scope of this thesis.

Although the levels of complexity proposed by Boulding (1956) offer insight into the range in characteristics from static to social systems, other works have sought to provide further guidance into the characteristics of complex systems. A *complex adaptive system (*CAS) is a type of system that possess three elements (Levin 1998, p. 432):

1) Sustained diversity and individuality of components
2) Localised interactions among these components
3) An autonomous process that selects from among those components, based on the results of local interactions, a subset for replication or enhancement

In a further iteration on CAS, Levin (2003) is careful to point out that not all complex systems are adaptive. Schneider and Somers (2006) makes this demarcation clearer, arguing that behaviours such as chaos, emergence and adaption delineate complex, adaptive systems from other open systems. A further perspective on such systems is

by Anderson (1999), who states they possess four unique states: (1) agents with schemata, (2) self-organising networks sustained by material importation, (3) coevolution to a boundary between order and chaos, and (4) recombination and system evolution. Further discussion of chaotic behaviour is conducted in section 2.3.2.

2.2.4 Goal-Seeking

This thesis also explores the idea of goal-seeking behaviour as a paramount function of systems. Goal-seeking behaviour is reflected in the actions or choices that seek to achieve a particular outcome (Adams et al. 2014; Whitney et al. 2015). The definition of these goals is contextual; for example, an organisation may seek to achieve established business goals, a biological system may act to ensure survival. Although the ultimate goal in any system may be of ensuring viability, or the ability to maintain independent existence (Beer 1984), multi-goal seeking behaviour may delineate across a variety of different system goals. As systems possess sub-systems and are part of large suprasystems, the idea of goal seeking behaviour can be extended to include variation amongst goals within different system levels.

Systems may be able to achieve specific goals through different means and conditions (Ackoff 1971). Hence, such behaviour can be expressed as leading to both *equifinality* or *multi-finality* (Whitney et al. 2015). Equifinality refers to the capacity of a system to reach its stated goal (or state) through a variety of different behaviours and paths (Von Bertalanffy 1950a). The factors that determine these paths are

various, however by allowing multiple trajectories to the same goal, equifinality falls in contrast to path dependency (Schneider & Somers 2006), or strict causal linearity displayed in closed systems (Kast & Rosenzweig 1972). As closed systems display this level of strict causal linearity (informed by opposite variable feedback loops), it is stipulated that equifinality is often restricted to open systems, due to their innate ability for material importation (Von Bertalanffy 1950a). Therefore, this suggests that systems may adopt several strategies (or paths) to return to acceptable performance after a disruption. Contextually the design of a logistics network supports this; as multiple routes and modes can lead to the same destination.

Although equifinality is a common factor within most systems theories, Whitney et al. (2015) argue that the converse of equifinality is true. Namely, systems can possess multi-finality, whereby multiple end states are attainable from the system initial conditions. Multi-finality may be linked to chaotic oscillations, whereby systems will become disorganised from an initial state of organisation (Kauffman 1991; Lorenz 1963).

Another perspective of goal-seeking is that systems will aim to maintain a steady state equilibrium (Holling 1973), leading to the potential of alternating between varying states; both of stable equilibrium (MacArthur & Levins 1964; Walby 2007), and of failure (Scheffer et al. 2001; Walker et al. 2004). Such a phenomena is referred to as shifting between *basins of attraction* (Gallopín 2006; Holling 1973; Walker et al. 2004), a 'landscape' (Walker et al. 2004) whereby system performance

precariously maintains an equilibrium between competing system states of order and chaos. The existence of numerous basins of attractions is a result of non-linearity amongst the vast array of uncertain events and their component interactions (Levin 1998) and may lead to a system surviving or failing (May 1977), or at times utilising positive feedback loops to move towards new equilibria (Walby 2007). Therefore, it can be argued that nonlinear behaviours emerging from disruptions may shift a system towards new basins of attractions.

2.2.5 Agents within Social Systems

2.3 Nonlinearity within Open Systems

System behaviour is not constant or universal, and systems can display behaviours ranging from equilibrium to randomness and chaotic oscillations (Sterman 2000). Therefore a key criticism of the original GST model is that key characteristics — namely equifinality—may not be applicable towards nonlinear systems (Schneider & Somers 2006). Argued as being a key component of 'real' (i.e. non-modelled) systems (Forrester 1987), non-linearity occurs when effect is not solely determined by cause (Sterman 2000), reflecting a shift away from linear functions whereby the outcome is solely a weighted sum of its inputs (Holland 1995). The simplest nonlinear behaviour is when the outcome is the product of two inputs rather than the sum; Holland (1995) uses predator-prey oscillations as an example of this phenomenon.

Non-linear behaviour arises due to a variety of causes. Firstly, the exposure of open systems to exogenous interactions render the system susceptible to perturbations (Blackhurst et al. 2005), such as the 9/11 terrorist attacks impacting the ability of logistics networks to operate (Sheffi 2005a).Another explanation is that localised system behaviour may not apply in periphery parts of the system (Sterman 2000). The emergence of nonlinear behaviour is often explained as an outcome of feedback loops; causal links between system components (Pruyt 2013). The implication of these particular behaviours is that systems may become more sensitive to small changes (Buckley 1967), potentially leading to uncertain outcomes.

2.3.1 Risk

The ability of open systems to engage with their exogenous environment renders them susceptible to events that can degrade system performance and viability. Risk events—as a sub-class of events with uncertain outcomes— differ from general uncertainty as they constitute a loss[3] (Kaplan & Garrick 1981) and are referred to as *disruptions* within the context of this thesis.

Such events are prevalent throughout a number of literature streams; with contextual examples including disasters (Farazmand 2007; Mackay et al. 2019), organisational crisis management (Mehta & Xavier 2012; Pearson & Clair 1998), supply chain uncertainty (Flynn et al. 2016) and threats to ecosystems (Scheffer et al.

[3] Events that constitute a loss are defined as disruptions; whereas the more general 'perturbations' does not necessarily invoke a loss within system performance.

2001). Often the individual literature is centred around a defined magnitude of disruption, as both the disaster and organisational crisis management literature can be regarded as focusing on high-magnitude events.

Christopher and Peck (2004) argue that—for supply chains—risk events can be categorised as being internal to a firm, external to a firm (i.e. supply and demand-side) and external to the network (i.e. environment). This thesis argues that these supply-chain orientated disruption types can be extrapolated towards any open system.

Risk is often conceptualised according to an event's probability of occurrence, and the magnitude of its consequences or outcomes (Kaplan & Garrick 1981; Sheffi & Rice Jr 2005). Although this particular matrix has been a popular tool for classifying risks (Cox Jr 2008), dependency upon this matrix falls short in situation where probabilistic risk calculations may be incorrect (Haimes 2009) or where there is considerable potential for decision making bias (Slovic 1987; Tversky et al. 1982). Furthermore, the utility of these metrics becomes questionable due to the ambiguous nature of uncertain events and outcomes (Cox Jr 2008).

Expanding upon the traditional quantitative assessment of probability versus magnitude discussed by Kaplan and Garrick (1981), various works by Yacov Haimes (1998, 2006, 2009, 2011) propose a systems perspective for understanding risk. Rather than conceptualising risk as a function of an event's probability and magnitude, Haimes (2009) argues that a systems-based philosophy provides greater guidance of

understanding risk to a system. Notably, Haimes (2009) proposes that risk is a function of: (i) time (ii) probability of the event (iii) magnitude of the consequences (iv) vector of system states and (v) vector of consequences. The interaction of extant states can influence the vulnerability of a system (Haimes 2006), which can be expressed as both an outcome (i.e. synonymous with consequences) or input of system behaviour (Bongiovanni & Newton 2018).

The inclusion of time as a component of system risk is important as disruptions are often subject to a temporal reality (Sheffi & Rice Jr 2005), whereby disruption discovery and impact may occur immediately or subject to lag (Craighead et al. 2007). Furthermore this temporal scale can reflect the speed which an event folds (L'Hermitte et al. 2014; Mackay et al. 2019; Van Wassenhove 2006), and the vulnerability of a system at given point in time (Svensson 2002), as a system may be susceptible to various disruptions at different points in time (e.g. a retail store experiencing an anticipated surge of demand).

The idea of consequences espoused by Haimes (2016) refers to the output of a system model, linked to the threat type (i.e. input) and interactions with extant states. As an output, consequences may not be experienced in the same manner across all system components (Haimes 2011), therefore the framing and behaviours of subsystems becomes a point of demarcation which will be explored in Chapter 4 and Chapter 5.

2.3.2 Chaotic Behaviour

As a type of nonlinear behaviour, chaos espouses sensitivity to initial conditions or small changes—common within high-level complex systems (Buckley 1967)—can result in a large variance amongst outcome trajectories (Lorenz 1963; Werndl 2009) leading to widespread disorganisation (Kauffman 1991). A common and popularised component of chaos is the so-called 'Butterfly Effect' (Kauffman 1991, p. 78):

> Chaos in the weather is exemplified by the so-called butterfly effect: the idea that a butterfly fluttering in Rio de Janeiro can change the weather in Chicago.

Therefore, when a system is not operating in equilibria (e.g. after a disruption), minor changes can potentially change the direction of the entire system (Walby 2007). Although a by-product of non-linear system behaviour, chaotic behaviour is deterministic (Thietart & Forgues 1995), linking back to variations in initial conditions, therefore not displaying pure randomness. Accordingly, once-stable systems can drift into disorganisation, and vice versa, as organisation may spontaneously emerge from seemingly disordered systems (Kauffman 1991).

Based on the view that systems possess characteristics both ordered and chaotic in nature (Upadhyay 2009), certain systems are able to exist in equilibria between these two contrasting states, referred to as the *edge of chaos* (Baym & Hübler 2006; Skufca et al. 2006; Upadhyay 2009). The shift towards this state can be attributed to competing forces pushing behaviour towards conflicting states of order

and disorder (Thietart & Forgues 1995). This literature can be linked towards the ideas espoused earlier surrounding basins of attractions; namely that in the face of a disruption, a system may find itself drifting precariously towards disorder, and accordingly particular strategies (discussed later in the chapter) may be used as a tool to guide a system towards viability and order.

2.4 Robustness and Resilience

Although both the occurrence and magnitude of disruptions can lead to nonlinear—and perhaps chaotic—system behaviours, systems will possess innate states that may serve as buffers against the probability and magnitude of a disruption or guide the system back towards viability. Two commonly discussed system are robustness and resilience. Although other states exist (see Haimes 2009), these two are discussed as they offer a holistic picture of how systems can behave post disruption.

2.4.1 Robustness

Robustness refers to the insensitivity of system performances to variations caused by stochasticity and disruptions. Quite often a system will have a robustness threshold, whereby disruptions of a probability or magnitude that exceed this threshold will lead to performance degradation (Haimes et al. 1998; Holling 1973). Research also states that robustness is inclusive of specific damage to system components (Vlajic et al. 2012) and general environmental volatility (Klibi et al. 2010). Robustness has also been linked with strength and durability (Mens 2015), sensitivity of design characteristics (Haimes 1998), resistance (Asbjornslett 1999) and decision flexibility

(Klibi et al. 2010; Rosenhead et al. 1972). Conversely, a lack of robustness can be expressed as sensitivity towards disruption perturbations (Zhou et al. 2017; Žiha 2000).

Within the engineering literature, robustness is often linked to system components such as reliability; in that a system is reliable if it is robust (Ben-Haim 1995). A perspective within the literature is that robustness can be challenged from both event-based (i.e. disruptions) and demand-based sources. An example of this is the work by (Zhou et al. 2017) on road network robustness, whereby *structure-based* and *traffic-based* exist as two to measure robustness; with the former measuring robustness against events, and the latter with general traffic flow (Zhou et al. 2017).

Robustness in the risk literature follows a similar pattern towards engineering definitions. Mens (2015) discusses robustness as part of a system's response curve, encompassing resistance threshold, proportionality (*suddenness* of response) and manageability. Haimes (1998, p. 174) links robustness to the hardness of a system, arguing:

> A system is hardened if the new optimal design is robust at a probability level equal to or larger than that of the original system. Most large-scale systems have a built-in buffering capacity i.e., the demand capacity is less than the system's safe yield: the greater the difference, the greater the system's buffer. Thus, the greater the safe yield is relative to the demand capacity, the more robust the system.

Robustness is contextual; in that a system is robust towards specific perturbations Jen (2003). Within the ecology literature *resistance* is often used synonymously with robustness, referring to the degree of variable change after a perturbation (Pimm 1984). Resistance is often expressed as the topology of a basin of attraction; with basins with a greater depth demonstrating greater resistance to change (Walker et al. 2004). The ideal basin of attraction influences system trajectory as most systems will seek a basin of steady state stability (Walker et al. 2004).

Robustness has emerged as a property of supply chain management.Robustness can be linked towards the capacity of a SC/operations system: measures such as Little's Law (Little & Graves 2008) are a popular mechanism for measuring capacity management within an operation. . Despite the emergence of robustness within the business literature as a measure of flexibility for environmental uncertainty (e.g. Rosenhead et al. 1972), its extant usage reflects other interdisciplinary definitions (Durach et al. 2015). Robustness has been treated as an indicator of uncertainty magnitude (Sokolov et al. 2016), reflecting a systems ability to continue despite particular sub-systems (i.e. nodes) being removed (Meepetchdee

& Shah 2007). Purvis et al. (2016) argues that robustness is temporal; reflecting a proactive response, rather than reactive system states (i.e. resilience). Accordingly, robust systems are able to withstand perturbations without adapting (Wieland & Wallenburg 2012). Therefore, robustness can be expressed as a 'trigger' between events being classified as a disruption; as low magnitude events that do not consume robustness will be absorbed into the general routines of a system.

2.4.2 Resilience

Resilience has a rich academic history across various disciplines (Haimes 2009; Holling 1973; Kamalahmadi & Parast 2016). Like a number of definitions discussed within the chapter, an interdisciplinary approach has led to variance in definitions. Despite this various, the main ideas discussed within the risk literature—emphasising the ability to recover within acceptable timeframes and losses (Aven 2011; Haimes 2009)—is evident across other disciplines.

Resilience plays an important role in supply chain risk management (van der Vegt et al. 2015; Wieland & Wallenburg 2013) as a means to respond to disruptions (Kamalahmadi & Parast 2016). Although emphasis has often been on actions to enhance resilience within a supply chain (Kamalahmadi & Parast 2016), it is also recognised that resilience may be an emergent characteristic, whereby resilience changes alongside other system states (Day 2014).

Ecological interpretations of resilience discuss perturbation absorption and resistance to change over time (Holling 1973) dependent upon the dynamics of a

given system (Walker et al. 2004). Often resilience is centred around a return to equilibrium—or a similar state of order—in the face of perturbations (Ives 1995). The original Holling (1973) model of resilience—seen as the forefront of the term within ecological literature—argued that resilience reflects a system's return to a single equilibrium state. In contrast, other definitions discuss the existence of multiple equilibriums (Gunderson 2000), whereby a shift into these alternating states may reflect either optimal or suboptimal outcomes (Walker et al. 2004).

Despite the lack of a general interdisciplinary definition, the core attributes of resilience can be narrowed down to an ability to withstand the effect of a disruption – to the point where the threshold towards the failure basin is not exceeded, recover within acceptable timeframe, and within elastic boundaries (Rice & Caniato 2003). Therefore resilience itself implies a degree of continuity (Ponomarov & Holcomb 2009) in ensuring the ability to meet performance objectives; Spiegler et al. (2012, p. 6170) discuss supply chain resilience as the 'impact any disruption has on the end customer'. Resilience can also be both strategic and operational (Munoz & Dunbar 2015), differentiating between a system's innate resilience, and the resilience only attainable via agent intervention.

Furthermore resilience is not a static variable but cultivated from multidimensional system states, as argued by Haimes (2016, p. 57):

> …the resilience of a system can be measured in terms of the specific threat (input), the system's recovery time, and the associated composite consequences in terms of costs and risks. Thus, different attacks would generate different consequences (output) trajectories for the same resilient system.

Thus, it becomes apparent that the contextualisation of disruptions is important. Namely, the nature of disruptions, coupled with the behaviour of extant system states (including individuals) influences the resilience of a system at a given time.

2.4.3 Comparing Robustness and Resilience

Resilience is often associated with recovery (Melnyk 2014), and differs from robustness due to its temporal focus rather than just the perturbation experienced by a system as defined by robustness. Christopher and Peck (2004, p. 4) argue that the two terms have "quite different connotations", despite being used interchangeably in practise. A common argument is that robustness is a component of resilience, and this approach appears interdisciplinary, with examples including ecology (Walker et al. 2004), information systems (Erol et al. 2010), disaster management (Bruneau et al. 2003) and supply chain literature (Durach et al. 2015; Wieland & Wallenburg 2013).

However, this is not a universally held position. Within ecology, for example, a number of authors argue that they are both distinguishable system states (Carpenter et al. 2001; Wertz et al. 2007). Additionally, works within risk management literature (such as Aven 2011; Haimes 1998) argues that resilience and robustness are interrelated, but separate, system components. Accordingly, the

stability of dynamics can be expressed as either a product of robustness (through perturbations not shifting system trajectory) or resilience (system rapidly returning to a similar dynamical state). For example, Jen (2003, p. 12) states that:

> A dynamical system is said to be structurally stable if small perturbations to the system itself result in a new dynamical system with qualitatively the same dynamics.

Other perspectives follow a similar pattern of differentiation. For example, Wang (2013, 2016) argues that although they are overlapping, high levels of one may result in low levels of the other.

Summarising the literature discussed above, system robustness can be thought of as countering the ability of a disruption to cause performance degradation to the point where disruptions of sufficiently great severity will result in performance degradation and exhibit sensitivity to the disruption, therefore negating the need for resilience. Viewing robustness and resilience as separate yet related properties of a system, resilience emerges when robustness is overwhelmed, therefore any investment in resilience within a highly robust system becomes unnecessary.

2.5 Summary of Literature on Systems

Any dynamic system can be expressed across several key factors including openness, goal-seeking behaviour, complexity and self-organisation. When facing non-linear behaviour—arguably a by-product of 'openness'—the transient response can be explained through a variety of interdisciplinary frameworks.

This first half of the chapter has aimed to provide a synthesis of the core literature surrounding systems pertinent towards this thesis Namely, the focus has been on the literature of open systems facing risks. By adopting an interdisciplinary perspective—borrowing heavily from the ecology, risk and supply chain management literature—several conclusions about the systems literature can be drawn.

Whilst closed systems drift towards entropy, open systems may find themselves following a similar trajectory unless the system responds in such a way to avoid this shift. The manner of this system response can be attributed to several causes, however for social systems this response will inevitably be driven by human decision-making processes. These processes are discussed in the second half of the chapter.

Secondly, complex systems are inherently difficult to explain due to the multitude of factors influencing behaviour. Adopting a holistic systems approach (where behaviour can be explained by sub-system interaction) does not necessitate a reductionist approach of understanding every variable and their role, but rather a top-down approach where components can be analysed where deemed appropriate. Therefore, from the literature several key systems states can be identified; namely nonlinear behaviour (such as chaotic behaviour emerging from deterministic processes) and the post-disruption emerge of robustness and resilience. As discussed, these states may be influenced by the role of individuals as agents within

social systems, therefore the following half of the chapter aims to explore how individuals make decisions in greater detail.

However, a key gap within the system literature appears to be incorporating the role of individuals who possess a degree of agency (discussed below). As a substantial part of the literature explored in the first half of the chapter has discussed systems from risk and ecological perspectives, the role of independent subsystem components is, at times, not considered. In order to harness a true holistic view of system behaviour, the following half of the chapter will explore the role of individuals within systems and the various factors that influence their ability to act as autonomous agents.

2.6 Decision Theories

The first half of the chapter explored literature surrounding the sometimes-intangible concept of a system. However, as outlined in Chapter 1 the thesis is focused around a particular type of system; namely those that are governed by human actors. Accordingly, this latter half of the chapter aims to provide an overview of a number of key decision-making theories and ideas before focusing on the predominant theory that will inform the latter half of the thesis.

As variation in system parameters can influence the number of stable states a system may possess (Gallopín 2006), it is suggested that sub-system components can influence these dynamic parameters. One of these components—that serves as a foundational component of the thesis—are individuals (or agents) within social

systems. The core argument expressed within the literature reviewed below is that individuals become agents when they possess a degree of decision-making power. Therefore, within the context of social systems, all agents are individuals but not all individuals are agents. . Social systems reflect a type of systems defined by the activities of human actors (Whittington 1992), and thus are the core focus of the thesis. Linking human actors within specific systems, Bandura (1989, p. 1175) argues:

> Persons are neither autonomous agents nor simply mechanical conveyers of animating environmental influences. Rather, they make causal contribution to their own motivation and action within a system of triadic reciprocal causation.

Triadic reciprocal causation refers to the interactions between behaviour, cognition and the environment in influencing individual choices (Bandura 1978). Therefore, the interactions individuals have within their system, and other sub/supra-systems, influence their role as individuals with agency.

Agency encompasses both the intention and capability to undertake a particular action (Giddens 1984). Agency is not restricted to the individual; Bandura (2000) attributes this idea to a collective interdependence by a variety of actors, working together to achieve a common goal. Although it is difficult to attribute agency to abstractions such as organisations (Wilmot 2001), it can be argued that individuals within these systems possess varying degrees of both perceived and actual agency.

Agency can be expressed as control over a particular process or scenario (Sewell Jr 1992) and the motivational components to act (Giddens 1979). Control therefore implies both a degree of efficacy (Bandura 1989) and a degree of power (Giddens 1984). In terms of efficacy, Bandura (2000, p. 75) emphasises the importance of perceived efficacy:

> It affects behaviour not only directly, but by its impact on other determinants such as goals and aspirations, outcome expectations, affective proclivities, and perception of impediments and opportunities in the social environment.

The inverse is also true; that once individuals lose power, they lose agency (Giddens 1984). Linking back towards the arguments presented within the thesis, it can be stipulated that for social systems—primarily where individuals operate within respective sub-systems—that perceptions surrounding agency and efficacy can influence actions that are an input into system behaviour.

The importance of including agents when analysing systems is discussed in a triadic model of the relationship between a disruption, system and decision-making in Scheibe and Blackhurst (2017). Although this model is develop based on (1) supply chain networks and (2) managerial decision-making, the thesis argues that three components can be universally applied to individual decision-making within systems facing disruptions.

Due to the frequency of choices being made by individuals, decision theories exist to distil choices into rationale frameworks (Slovic et al. 2000). Individuals engage with decision-making rationales to assist in creating choices every day. Beach and Mitchell (1978, pp. 441-442) delineate choices into:

1) Aided-analytic methods: procedures to assist decision guidance
2) Unaided-analytic methods: mental models
3) Routine methods: Predetermined rules (such as a coin toss to indicate choice)

Choices can be expressed as an *act*, or the particular path undertaken by an individual within a certain set of circumstances (Fishburn 1981)[4]. The path followed by an individual can be viewed as the end-result of a process that frames the outcome of choice according to established goals. These goals are often based on particular qualities that an individual perceives, whether that be for satisfaction (Bernoulli 1738), protection against a perceived threat (Rogers 1975) or some other qualification (such as a work-based task). Therefore, within goal-seeking systems an individual may make decisions to ensure they reach their goals within an acceptable timeframe and manner.

The consequences of engaging particular paths will allow individuals to compare the difference in utility between choices (Fishburn 1981; Louviere et al. 2000). Therefore, in similar behaviour to the systems idea of equifinality discussed

[4] The thesis follows the Fishburn (1981) definition of choice but differentiates choice (i.e. the intention to undertake a particular path) from action (the actual undertaking of the chosen path).

early in the chapter, an individual might engage in a process of comparison, whereby they compare multiple paths to achieve the same outcome. Within each of these scenarios, the differentiating factors between various paths available for individuals is often related to the effectiveness and optimality of a particular set of choices (Beach & Mitchell 1978). Furthermore, there is often a demarcation within choice-evaluation procedures between automatic actions (i.e. reacting to a sudden sound) and allocating attention towards tasks (Kahneman & Egan 2011).

Understandably, there is an overarching abundance of literature on decision theories. Models have been proposed, and tested, as a means of ensuring theoretical dominance of a particular choice theory (Harrison & Rutström 2009). Despite the substantial number of decision theories that exist in the literature, it can argued that the vast majority of theories have common linage to the foundational ideas of utility theory, first formulated in the 18th century (Bernoulli 1738; Edwards 1954).

2.7 Utility Theory

The original propositions of utility theory by Bernoulli (1738) stipulate that value is determined by hedonic qualities rather than solely by price. Expanding on this original perspective, Bentham (1823, p. 1) argues that these hedonic qualities—expressed as outcomes of a choice—are *pleasure* or *pain*:

> It is for them [hedonic qualities] alone to point out what we ought to do, as well as to determine what we shall do. On the one hand the standard of right and wrong, on the other the chain of causes and effects, are fastened to their throne.

Bentham recognises the intense use of metaphor in the above phrase, and there is substantial difficulty in measuring hedonic principles that are ultimately subjective (Kahneman & Snell 1990; Kahneman et al. 1997). Although this led to a schism in academic thought between the Benthamism pleasure-pain binary (that is *experienced* utility), and the more modern adage (*decision* utility) Kahneman et al. (1997) argue that experienced utility is, in-fact, a measurable phenomenon. Experienced utility can be viewed as two functions; the *instant* utility of an action, and the *remembered* utility that an individual will apply retrospectively (Kahneman et al. 1997). However rather than individuals maximising utility through repeated choices, utility is inversely proportionate to quantity; a phenomena referred to as *diminishing marginal utility* (Bernoulli 1738).

2.7.1 Assumptions of Utility Theory

The theory itself makes three major assumptions; that an individual will possess complete information, infinite sensitivity and will behave in a rational manner (Edwards 1954). A variety of factors—both endogenous to an individual and exogenous forces influencing them—impact the ability for individuals to act in accordance to these assumptions. An individual's ability to choose amongst fixed and known alternatives can be impacted by their perception and cognition (Simon 1959), and the environment in which they operate (Simon 1972). Individual

knowledge also plays a large role in the level of uncertainty (Haimes 2016), particularly concerning the perception of events involving losses. Such knowledge can include the accumulation of data, evidence and previous experience, and can increase the uncertainty surrounding a particular choice function (Kaplan & Garrick 1981). Misperceptions of feedback, particularly from information that individuals receive and analysis, can lead to misguided choices and non-optimal performance (Sterman 1989). Accordingly, individuals may make decisions based upon the *subjective* experience of the outcome (Kahneman & Snell 1990), acting as a driving force for an individual to maximise their utility based upon perceived outcomes (Kahneman et al. 1997).

It is further important to consider that utility can be constructed across a wider range of individual determinations. Firstly, the utility can be either positive or negative depending upon the outcome of a situation (Edwards 1954), as individuals may choose to sacrifice short-term positive outcomes for long-term gain. Additionally, utility can be influenced by the interactions surrounding conflict and cooperation between individuals, as they will act based upon the actions of those involved in the same system (Myerson 1991; Von Neumann & Morgenstern 1944). This premise (referred to as *game theory*) has its own stream of literature however it falls outside the scope of this thesis.

2.8 Decision-Making under Uncertainty[5]

Incorporating risk and uncertainty into decision-models limits individual rationality (Simon 1972). Indeed, many scenarios exist whereby the trade-off involves notions of risk, or loss (Friedman & Savage 1948). Gambling and insurance serves as two most prolific examples of decision-making under risk and assume that the outcome is both uncertain and may possess a loss. The rationale for developing decision-rules in these scenarios is often linked towards subjective constructions of real world phenomena (Simon 1959; Slovic et al. 2000). A clear example of how subjective constructions influence choice rationales is the Gambler's Fallacy, whereby streaks that occur within random distributions lead to significant biases (Oppenheimer & Monin 2009). Often, this process leads to individual's applying previous outcomes as indicators of future behaviour (Sundali & Croson 2006, p. 1):

[5] The thesis acknowledges the various semantical discussions surrounding phrases such as choice, decisions and strategies. Whilst these are defined in the Glossary, for the purposes of this thesis choice and decision are occasionally used interchangeably. As discussed later on within the thesis, 'strategy' refers to a particular choice type in reference to decision-making against disruptions.

> For example, imagine Jim repeatedly flipping a (fair) coin and guessing the outcome before it lands. If he believes in the gambler's fallacy, then after observing three heads in a row, his subjective probability of seeing another head is less than 50%. Thus he believes a tail is "due," and is more likely to appear on the next flip than a head.

2.8.1 Heuristics of Choice

The drivers that lead individuals to make misaligned choices—as demonstrated within the Gambler's Fallacy—has driven a significant body of research towards explaining the factors that lead to the misperceptions of outcomes. One such argument is that individuals will deploy specific judgements—referred to as *heuristics*—as a means of reducing the complexity of probabilities by forming simple judgements of values (Tversky et al. 1982) that can occur both consciously and unconsciously (Mousavi & Gigerenzer 2014). The works of Finucane et al. (2000); Tversky and Kahneman (1973); Tversky et al. (1982) propose four key heuristics that individuals deploy: representativeness, availability, anchoring and adjustment, and affect. For scenarios where individuals will not possess perfect information, heuristics offer an insight into how individuals will construct non-rational judgements.

Heuristic	Description
Representativeness	The degree of similarity between two phenomena that results in a particular probability (Tversky et al. 1982)
Availability	Subjective probabilities of occurrence are assigned to particular events based on the ability to recall or imagine such scenarios (Tversky et al. 1982)
Anchoring and Adjustment	Individuals may start from an initial value and adjust their response towards a final answer (Tversky et al. 1982)
Affect	Individuals will make a choice based on the subjective valence of an event and its consequences (Finucane et al. 2000)

Table 2.4 Heuristics for Judgements under Uncertainty (adapted from Tversky et al. 1982, Finucane et al. 2000)

However, measuring the impact of these heuristics on individuals becomes difficult due to the method of elicitation and context of choice (Tversky & Kahneman 1992). One area proposed to address this is the individual framing of events as either resulting in a gain or loss, regarded as having important weight on choice protocols. Prospect theory (first proposed in Kahneman & Tversky 1979; and later revised in Tversky & Kahneman 1992), argues that rather than rational invariance leading to identical preference orders, individuals will frame outcomes based upon their perception as a gain or loss. A core component of prospect theory is that individuals will frame a loss greater than a gain (Kahneman & Tversky 1979), resulting in a tendency towards loss aversion (Tversky & Kahneman 1992). This leads to a variance amongst traditional utility-based models that assume a static curve (i.e. marginal diminishing utility), shifting the individual behaviour to their perceived

outcome of an action as two separate functions of gain and loss (Harrison & Rutström 2009).

2.8.2 Intuition and Reasoning

Another perspective on how individuals make decisions under uncertainty is associated with a dual-process of choice between intuition and reasoning (Evans 2003), coined by Stanovich and West (2000) as System 1 and System 2. Although the literature surrounding cognitive duel-processing is prominent within the cognitive psychology literature (Evans 2008), it is also emergent in various works within the decision sciences literature (Kahneman 2003). The main differential between these two cognitive systems is those choices that are automatic and immediate, and those that are slow and deliberate (Evans 2008); defined by Kahneman and Egan (2011) as *fast* thinking (system 1) and *slow* thinking (system 2).

System 1 consists of automatic thought operations that almost immediately lead to a choice or answer, similar in some respects to the idea of unaided analytical processes discussed in Beach and Mitchell (1978). As they are automatic, System 1 judgements are often based on small data pools (Ball & Watt 2013) and at times follow intuitive perceptions of an event (Paté‐Cornell & Cox Jr 2014). Similar towards the aided-analytic process, System 2 deals with constructing thoughts through a more thorough, step-by-step process. Thus, this system is often linked to rationale, rules-based analysis (Evans 2008) based on analytical processing (Stanovich & West 2000).

System 1	System 2
Fast	Slow
Automatic	Controlled
Associative	Rule-based
Slow-learning	Flexible
Emotional	Neutral
Low Effort	High Effort

Table 2.5 System 1 and 2 Processes, adapted from Kahneman (2003), Evans (2008)

These two systems are intertwined; often System 1 will lead into System 2 (Kahneman & Egan 2011) as individuals seek to support already-established intuitions (Ball & Watt 2013). In other words, intuition can influence slower judgements based on reasoning. However, under certain conditions—such as how individual frame event outcomes—slower, rational judgements can override individual reactionary intuitions (Kahneman 2003).

2.9 Risk Perceptions[6]

The theories (and associated components) of decision-making under uncertainty are often tested with experimental designs. Accordingly, it becomes difficult to adopt a

6 The thesis acknowledges variance in definitions of expectations and perceptions. Works by Parasuraman et al (1985) and Olson and Dover (1979) define expectations as mental constructions concerning beliefs about an event prior to its occurrence, whereas perceptions are post-event comparisons between expectations and actual performance.
For the purposes of clarify, the thesis will follow the risk perception literature in using the phrase 'perception' as the predominant term to encompass mental constructions about an event. The thesis avoids attaching the phrase to a temporal scope as mental constructions are emergent over time; for

systems perspective on such theories, as they are—by their own design—restricted to the individual. Furthermore, they are often restricted towards evaluated responses to events where outcomes are known and measurable, therefore potentially running the risk of ignoring unknown-unknown events that have not occurred before, also referred to as *Black Swans* (Taleb 2007).

A branch of theories arising primarily from psychology literature (as the focus is on behaviours rather than monetary), concerns itself with discussing choice rationale for exogenous threats, where the outcomes of events can transcend monetary gains or losses. Risk perceptions arose as a means of explaining the ability of individuals to sense and act towards mitigating the impact of hazardous events (Slovic 1987), adopting an event-focused (i.e. contextual) perspective on decision-making under uncertainty. Risk perception research aims to explain the disparagement between technical and social assessments of risk (Kasperson et al. 1988). Accordingly, it follows on from the bounded rationality approaches discussed within decision-making under uncertainty.

2.9.1 Defining Risk Perceptions

Risk perception research often distils risk into a probability-and-magnitude binary (Slovic 2000). Within this binary, risk is broadly expressed as a function of the probability and consequence of a scenario across a certain timeframe (Haimes 2009;

example an individual's perception of magnitude may exist both prior and after an event's occurrence.

Kaplan & Garrick 1981). Despite the issues with this binary (as discussed earlier in the chapter), variations of this binaryare frequented throughout the risk perception literature.

Slovic (1987) argues that risk perceptions arise from a *psychometric paradigm*, which produces a cognitive map of individual perceptions of hazardous events. The purpose of this map is to provide a taxonomic representation of individual assessment of an event's 'riskiness', in contrast to expert assessments based upon an event's perceived fatalities (Marris et al. 1997). Although the model has been critiqued due to its homogeneous classification of individuals as either 'lay people' or 'experts' (Marris et al. 1997), the two binaries within this model—continuums based upon the degree of which a risk is unknown, and its associated dread—have parallels to the probability-and-magnitude metric of risk espoused by Kaplan and Garrick (1981).

Another perspective on risk perceptions is the role of the decision-maker within their respective system. For public systems, Lichtenstein et al. (1990) refer to 'societal' decision-makers, whereby the utility of choice transcends from the individual to those they are tasked to serve. Shifting the utility function away from an individual to the system is commonplace within numerous contexts. For example, Ellis et al. (2010and); Kull et al. (2014) discuss the role of risk perceptions in influencing buyer behaviour within supply chain management. The study conducted by Kull et al. (2014, p. 461) supported the loss-framing arguments within

prospect theory, as managers would "generally avoid selecting a supplier with less certain outcomes even when that supplier possesses higher expected returns than the more certain supplier."

The events manifested from these perceptions are contextual and vary according to the literature discipline. As discussed earlier, traditional research of risk perceptions (Slovic 1987) focused on hazardous events (i.e. ranging from alcohol accidents to nuclear war). Other event types reviewed include risks to supply chain performance (Ellis et al. 2010; Flynn et al. 2016; Tukamuhabwa et al. 2015; Zsidisin & Wagner 2010), natural disasters (Bubeck et al. 2012; Miceli et al. 2008), health concerns (Weinstein 1993) etc.

2.9.2 Issues surrounding 'Probability' and 'Magnitude' in Risk Assessments

As discussed, theories surrounding risk perceptions often centre on the perception of an event's probability and magnitude. However, as highlighted earlier in the chapter this assessment can be biased due to incorrect calculations and decision-maker bias. A number of empirical studies argue that that the link between this traditional assessment of risk perceptions and decision adoption is at best indecisive, and at worst controversial (Wachinger et al. 2013). Another perspective on this is provided by Bubeck et al. (2012, p. 1493), who argues that, within the context of flooding:

> Our review of the current empirical literature has shown that the supposed positive relation between flood risk perceptions and the adoption of private mitigation measures is hardly observed in crosssectional (sic) studies.

Rather than basing choices solely on the perception of a disruption's probability of occurrence and magnitude of consequences, the factors that influence individuals to undertake a choice (in this context, mitigation from floods) are wider; including appraisals of choice outcome, costs and other cognitive constructions (Bubeck et al. 2012).

Although the lack of correlation between perceptions (i.e. probability and magnitude) and undertaking choice can be potentially attributed to methodological issues (Bubeck & Botzen 2013; Siegrist 2013), the shift away from probability and magnitude is a common factor within a number of theories. Another issue with probability as a metric for perceptions of risks is that it seldom considers events described by Taleb (2007, p. xxii) as 'Black Swan' events:

> First, it is an *outlier*, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility. Second, it carries an extreme impact (unlike the bird). Third, in spite of its outlier status, human nature makes us concoct explanations for its occurrence *after* the fact, making it explainable and predictable.

Accordingly, there has been an emergence of theories that utilise probability as only one antecedent of choice. The model adopted within this thesis—primarily due to its

emphasis on individual agency and efficacy—is Protection Motivation Theory (PMT).

2.10 Protection Motivation Theory (PMT)

Several theories have been proposed that incorporate probability as one aspect of individual assessments of risk. One theory of interest to the thesis—due to its applicability towards both individual choice and system outcome—is protection motivation theory (Maddux & Rogers 1983; Rogers 1975).

Protection Motivation Theory argues that the choice to undertake protective action against a particular threat will be adopted based on a mediating process concerning an appraisal of a threat and the coping mechanisms available (Rogers 1975; Rogers 1983). This appraisal process serves as the utility function; as individuals will adopt a particular response based upon their prior mediation.

PMT originally emerged as an explanatory model for health-protective behaviours (Weinstein 1993). In addition to its inferences from utility-based models, a core component of the original formulations of PMT is the idea of *fear appeals*, defined as communicative techniques whereby eliciting fear serves as the predominant driver for individual action adoption (Higbee 1969; Witte & Allen 2000).

PMT can be visualised as a three-stage model: (i) antecedent information leads to a (ii) cognitive mediating process, that (iii) informs whether to undertake protective

action. Although the model of PMT has similar hallmarks to that of traditional risk assessments—with the threat appraisal encompassing probability and consequence—efficacy has been a dominant theme influencing choice adoption within a number of studies discussed above. Further iterations of PMT have proposed a number of extensions to the original model. For example, Lindell and Perry (2012) argue that there are physical and environment impediments (i.e. constraints) that play a role in the appraisal process.

2.10.1 From Threat to Coping Appraisals

One of the driving factors that differentiates PMT from other utility-based models is the inclusion of efficacy as a driver of choice (Weinstein 1993). Self-efficacy refers to an inert belief that an action can be undertaken and thus influences the likelihood of a particular behaviour being adopted (Bandura 1977). Similarly, self-efficacy can be linked to control over a scenario (Bandura 1989), linking back towards individual agency (Sewell Jr 1992).

The coping appraisal occurs once a level of threat appraisal has been reached (Bubeck et al. 2012). Accordingly, an initial assessment of the likelihood and magnitude of a disruption can be view as the first step towards adopting a protective choice, which may occur even after the disruption has occurred (e.g. if the disruption was not perceived). Such appraisals potentially violate axioms of utility theory by arguing that although the expected utility of an action may be high, an individual still might not act due to their perceived inability to undertake a certain

choice (Bubeck et al. 2012). Therefore, there is potentially a link between an individual's perceived power (i.e. agency) and the decision to adopt protective action.

Empirical adoptions of PMT have challenged that role of traditional antecedents of quantitative risk assessments —namely probability of occurrence and magnitude of consequence (Kaplan & Garrick 1981) — as influencers of protective action (Bubeck et al. 2012). Literature reviews on PMT (Floyd et al. 2000; Milne et al. 2000) found a higher correlation between adopting protective action and its associated efficacy rather than the threat appraisal. Similar findings were found in literature reviews on flood preparedness (Bubeck et al. 2012; Poussin et al. 2014). Bubeck et al. (2012, p. 1481) go as far as to state that "risk perceptions as a means to explain and promote private flood mitigation behaviour is not supported on either theoretical or empirical grounds". This view is supported in recent empirical research into flood preparedness (Poussin et al. 2014) and across the wider risk perception literature (Wachinger et al. 2013). In a review of selected literature on risk perceptions since 2000, Wachinger et al. (2013, pp. 1062-1063) argue that a paradox exists in the assumption that higher risk perceptions will lead to preparedness and mitigation behaviour.

> It is generally assumed that high risk perception will lead to personal protective actions. However, this depends on many contextual factors, in particular the ability of the individual to recall past damages or, at least, to imagine the effects of a disaster. In addition, if people trust public authorities, they are more likely to take warnings seriously and act accordingly.

However, it is important to acknowledge that the recent empirical works that have drawn these conclusions have been methodologically similar, utilising quantitative research methods (i.e. surveys) as their primary method of analysis (Bubeck et al. 2012; McCaughey et al. 2017). Therefore, there is the possibility that utilising other methodological approaches (e.g. interviews) will offer additional insight into this debate. In addition, both the original and expanded models of PMT have been centred around the idea of an individual undertaking an action to protect themselves against physical harm. This is evident by the focus on health-related behaviour within the meta-analysis conducted by Milne et al. (2000) and recent applications of PMT into applied settings (Bubeck et al. 2012; Bubeck et al. 2018; Franklin et al. 2014). The reasoning behind this focus on health-related behaviour (against a physical harm) can be attributed towards the foundations of PMT within fear appeals (Rogers 1975). However, as noted by Wacker (1998), generalisability forms a core component of theory development. By adopting the core components of PMT (appraisals of threat and coping), the thesis argues that the theory can be used as a tool for measuring risk and disruption behaviour more generally. Therefore—as undertaken within the thesis—expanding PMT towards including other theories (i.e.

systems theory) and non-physical threats (such as disruptions to organisational performance) will contribute towards this ongoing discussion.

2.11 Extant Strategies for System Behaviour

Linking together the system characteristics and decision-making processes, several strategies for systems that face disruptions exist. These strategies are primarily drawn from literature streams that are influenced by systems theories, namely supply chain and operations, engineering and ecology. An important caveat to note is that the literature based on non-human actors (i.e. ecology) often discusses a strategy as a system-wide behaviour, rather than an active choice made by an individual. Accordingly, the following sections focus on human-based decision-making, with references to the ecology literature serving as a link between these strategies and the fundamental systems concepts discussed in the chapter above.

2.11.1 Redundancy and Flexibility

A common dichotomy, particularly within the supply chain and operations management literature, is to classify risk-based choices as redundancies (Sheffi 2005b) and flexibilities (Stevenson & Spring 2007). Despite their popularity within this literature stream, discussion surrounding their utility in mitigating disruption impact is ongoing (Kamalahmadi & Parast 2016). Within other literature streams

discussed later in this section, the phrases often have varying semantical definitions depending upon context[7].

Redundancy: Central to the notion of choices in redundancy is the idea of *doing more of the same*[8]. Redundancies aim to 'assume the functions of failed components without adversely affecting the performance of the system itself' (Haimes 1998, p. 174), or more succinctly holding additional resources in reserve to deal with disruptions (Sheffi & Rice Jr 2005). Systems will often possess redundancies as a means of ensuring safety and viability in the face of disruptions (Whitney et al. 2015).

Redundancies improve the robustness and resilience of a system for a given timeframe yet can be viewed as wastage when not consumed (Sheffi & Rice Jr 2005). Redundancies often act to assume the role of failed components after the disruption (Haimes 1998), or as a 'buffer' against uncertainty (Sheffi & Rice Jr 2005). When acting as a buffer against uncertainty, 'energy' can be imported from the external environment to avoid failure, contextualised as a counter against failure in the form of actions such as safety stock within inventory management systems. Redundancy receives frequent mention within the supply chain literature (Kamalahmadi & Parast

[7] Notably within a number of ecological papers the phrase 'flexibility' does not appear, whereas the synonym 'adaptability' is predominantly featured. Rather than treat these phrases as synonyms, the thesis argues that flexibility strategies result in adaptability; which is a system state, rather than a strategy. This guidance is interpreted both from Lee (2004), and the lack of differentiation between actor and system within a number of ecological papers.

[8] The simplification of redundancy as *doing more of the same* and flexibility as *doing things differently* are the author's own emphasis.

2016), often constituting actions such as inventory stockpiling and safety stock (Chaturvedi & Martínez-de-Albéniz 2016; Christopher & Peck 2004), increased resource pooling (Azadeh et al. 2014; Johnson et al. 2013) and multiple suppliers (Tang 2006). Within organisations, these additional resources are often not necessarily kept in the premises; therefore entailing strategies such as having multiple suppliers (Sheffi & Rice Jr 2005; Tang 2006), or even actions related to expediting and emergency replenishments when lead times are not negligible (Roni et al. 2016).

Flexibility: On the other hand, flexibility broad refers to a range of strategies simplified as *doing things differently*. These strategies represent the ability to restructure existing capabilities and assume a different position or configuration towards mitigating the magnitude of disruptions (Carvalho et al. 2012; Lee 2004; Tang & Tomlin 2008). Flexibility can exist in having the capability to reconfigure supply chain operations (Beamon 1999), or as an operationalization of agility in which system capabilities are changed in order to adapt (Ma et al. 2009; Swafford et al. 2006, 2008). Flexibility is addressed in supply chain literature as a means of countering lack of stability and predictability (Slack 1983, 1987). Within this context, flexibility is multifaceted and can relate to numerous echelons of a supply network (Stevenson & Spring 2007). Within the supply chain and operations literature, numerous flexibility strategies have been proposed to proactively deal with

uncertainty, such as product postponement and manufacturing flexibility (Tang & Tomlin 2008).

A point of disputation is the relative effectiveness of various strategies, particularly within the context of disruption mitigation and management. Although some authors argue that flexibility is more cost-effective than redundancies (such as Sheffi & Rice Jr 2005), factors such as limited resources within systems (and the resultant contextualisation of strategies) renders this discussion ongoing (Kamalahmadi & Parast 2016). A key point of interest within this thesis is the manner of which redundancy and flexibility emerge as two distinct choices. However, it is recognised that the simple classification of a choice as a redundancy or flexibility may not capture the holistic nature of choices within complex social systems. Accordingly, key consideration to be made is that both redundancy and flexibility strategies are subject towards a temporal scope.

2.11.2 Temporal Dichotomy

Temporalities—the timeframe under which an action takes place—are often designated as *proactive* and *reactive*. The term *proactive* refers to actions taken prior to the disruption occurrence and involves planning to either reduce the probability of occurrence (Thun et al. 2011) or mitigate the severity of disruptions (Knemeyer et al. 2009; Mitroff & Alpaslan 2003). Proactive actions focus on identifying potential losses related to disruptions and operating adequate countermeasures prior to disruption occurrence (Grötsch et al. 2013). Proactive action taken to minimise

performance losses against supply chain disruptions has been argued to be an effective way of managing risk (Tang & Tomlin 2008; Tang 2006). Proactive choices imply the existence of a detection or anticipation that a disruption will occur (Dabhilkar et al. 2016).

Furthermore, proactive strategies can also be utilised when a disruption has occurred, but the magnitude has not impacted the focal system. Within the context of supply chain networks, Zhao et al. (2019) argue that proactive strategies can be deployed when a disruption impacts peripheral firms but has not propagated within the network to the focal firm.

Conversely, *reactive* entails taking action after a disruption has occurred (Grötsch et al. 2013). Reactive choices are thus often associated with actions taken to minimize the detrimental impact of disruptions (Sheffi & Rice Jr 2005), with numerous cases in the literature arguing redundancies and flexibilities can assist systems cope reactively with the disruption (e.g. Christensen et al. 2015; Pal et al. 2014; Roni et al. 2016). Whilst particular disruptions can be prevented through proactive actions that limit the probability of occurrence (Chopra & Sodhi 2004), others can only be addressed by either preparing for their inevitable occurrence (Knemeyer et al. 2009) or reactive actions after the disruption is detected (Sheffi 2015).

A further perspective on the temporal dichotomy is that of 'stages' aimed towards mitigating the impact of disruptive events. Although it is recognised that

there is often no clear demarcation between these stages (Maon et al. 2009), they offer additional insight into the extant proscriptive guidance for risk management.

Borrowing from the humanitarian logistics (see Kovács & Spens 2009; Kovács & Spens 2007) and risk management literature (see Sheffi & Rice Jr 2005), these stages can be conceptualised as *preparation (*prior to the disruptions occurrence), *immediate response* (immediate aftermath of disruption) and *recovery* return to pre-disruption performance). Preparation implies the existence of a detection mechanism, which is often espoused as an important part of risk management (Sheffi 2015; Williams et al. 2017), however as briefly mentioned earlier in the chapter disruptions may occur with no previous perception (Taleb 2007).

2.12 Conceptual Framework and Conclusion

The literature reviews in this chapter has provided a lens for analysing the role of decision-making in influencing system outcome. Rather than assuming a strict causal relationship between choice and outcome, the multitude of factors that influence system behaviour suggest the relationship is more complicated. In a similar fashion, the literature on decision-making theories rarely make arguments concerning how choice impacts the behaviour of systems. In other words, individuals will make a choice based upon rationales—as outlined within specific theories—however the impact of that choice remains outside the scope of those theories.

Accordingly, the thesis seeks not to necessarily provide causal validation of the relationship between choice and the system, as this may only be contextually valid (to either a disruption or individual type), but to explore the nature of this relationship within further detail (this follows a systems perspective on theory proposed by Burton-Jones et al. 2015 that looks at interactions between components rather than causation) . Returning to the research questions proposed in Chapter 1, insights concerning the research questions are listed in Table 2.6.

Question	Results of Literature Review	Seminal References
(1) How do disruptions manifest themselves within social systems?	Social systems—as with any open system—are susceptible to disruptions arising from exogenous forces.	Von Bertalanffy (1950b); Whittington (1992)
(2) What are the main characteristics of disruptions?	Disruptions are contextual; from the supply chain literature they can be generalised as arising from supply-side, demand-side or internal sources.	Flynn et al. (2016)
(3) What are the antecedent and systemic circumstances that influence an individual's choice to make decisions when facing disruptions?	Antecedents are going to be derived from both individual circumstances and characteristics (which are outside the scope of the thesis). However, the role of feedback within dynamic systems suggests that choice may be influenced by particular system characteristics, both consciously and subconsciously.	Rogers (1983); Slovic (1987); Tversky et al. (1982)
(4) How do systemic factors influence an individual's agency to make decisions?	As more complex systems (i.e. social systems) are based on hierarchies with relation to sub and suprasystem components, individual agency and efficacy may be influenced by their interaction with other elements of a system.	Kast and Rosenzweig (1972); Levin (2003)

(5) What are the main dimensions of choice types?	Choices—with regard to decision-making against disruptions—are often conceptualised as being redundancy/flexibility and proactive/reactive.	Kamalahmadi and Parast (2016)
(6) What is the interaction between these choices (or lack of choices) and the system in which they operate?	The intersection between choices and the wider system is not clear within the literature.	
(7) How do disruptions manifest themselves within system behaviour?	Disruptions can be expressed as a type of nonlinear behaviour. A chaotic view discusses systems on the edge of chaos; a disruption may serve as a trigger shifting between states of order and chaos.	Upadhyay (2009)

Table 2.6 Results of Literature Review

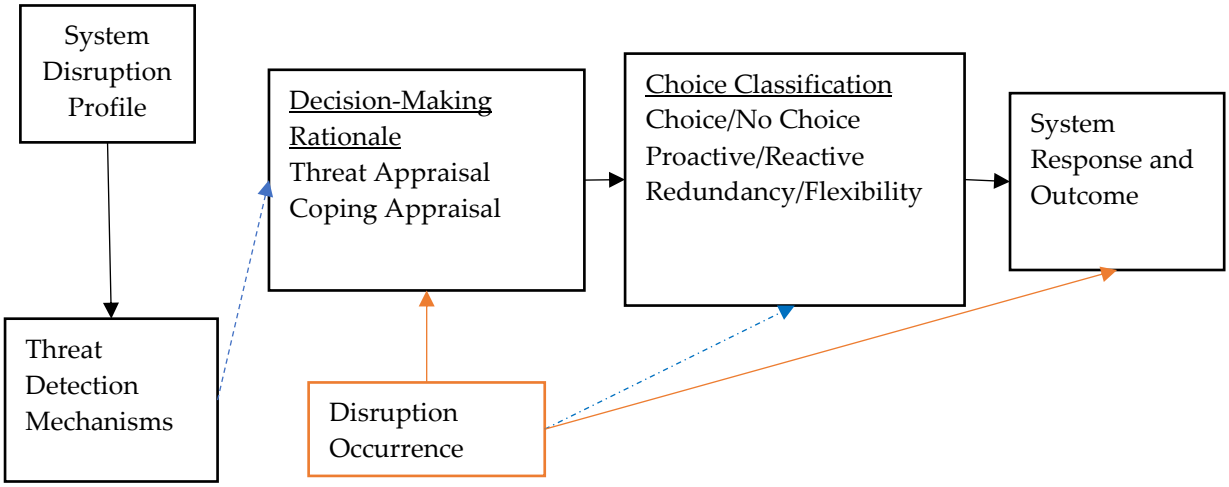

Figure 2.1 Conceptual Framework

Figure 2.1 represents the conceptual framework interpreted from the literature, synthesising both the choice appraisal processes and the system behaviour. The purposes of this model is to serve as an overview of the major themes to be explored within the interviews.

Figure 3.3 expands PMT by focusing on the system-wide states and dynamics emergent from a disruption. The overarching premise of the conceptual framework is that decision-making and resultant choice protocols can influence the transient response of a system, thus shifting it towards either a survival or perishing basin of attraction.

This chapter has aimed to review the pertinent literature to both systems and decision-making processes that influence system behaviour concerning risk-based events. Although both streams have a wealth of academic literature behind them, it appears that adopting a system's view of decision-making processes under risk—in particular for disruptive events—presents a gap of interest towards this thesis. Therefore, the following chapters seek to expand upon this wealth of literature by adopting a novel approach towards understanding the interplay between choice and system behaviour.

Chapter 3 Methodology

This chapter outlines this methodology and the research paradigm that underpins the thesis. In particular, the chapter focuses on discussing the adoption of semi-structured interviews based on the Critical Incident Technique (Flanagan 1954) as the primary research method used within the thesis.

The first section of this chapter looks at the traditionally used positivist research paradigm, and how concerns about the pursuit of universal truth has led to paradigmatic deviations towards constructivist (or naturalistic) ontological and epistemological perspectives. Adopting a constructivist perspective—whereby there can exist multiple realities of the same phenomena—this thesis follows a hermeneutic manner of interpreting meaning from text, acknowledging the epistemological interconnectedness between researcher and the phenomena to be researched. Espousing hermeneutics as a "middle-ground" between absolute relativism and absolute truth, the thesis follows an abductive research approach; whereby the theoretical frameworks discussed in the previous chapter, and emergent themes within the data, are given equal credence. Therefore, this abductive approach emphasises drawing interpretations from both extant (i.e. derived from the literature) and emergent (i.e. from data) sources of information.

In order to accurate reflect a constructivist research paradigm, it is recognised that the type of data collected for the thesis needs to coincide with the ontological

perspectives of multiple realities. Thus accordingly, a qualitative approach utilised semi-structured interviews based on the Critical Incident Technique (CIT) to explore individual experiences of disruptions and the systems in which they operate. These interviews are transcribed based upon a denaturalised approach that prioritised the content over interview transcripts over linguistic characteristics. The transcription of interviews followed a denaturalised, verbatim approach and are coded across two stages. The first stage reflects the proposed conceptual framework in section 4.51 that outlines the first-level codes. The second stage (discussed in Chapter 5) reflects the emergent codes elicited from the interviews.

The latter section of the chapter discusses how interviews were sought across a wide array of individual experiences, and the considerations made within the thesis to reduce the impact of interpretative bias. The chapter concludes with a discussion of data saturation, and the relevant saturation protocol established for this thesis.

3.1 Paradigms for Framing Research

The thesis follows a hierarchical order of inquiry proposed by Guba and Lincoln (1994), whereby the research paradigm for a given endeavour can be delineated into a series of assumptions about the nature reality. This hierarchical order follows three main questions; the *ontological question* (concerning the nature of reality), *the*

epistemological question (concerning the nature of knowledge) *and methodological question* (concerning how the 'inquirer' can obtain knowledge').

Variance amongst the overall research paradigm results in different interpretations of these questions. A common focus of scientific-method driven research has been through adopting a positivist approach, whereby realistic considerations about reality are developed (Guba & Lincoln 1994). Such an approach leads to an understanding of knowledge that is quite objectivist and result in methodologies that aim to test hypothesis against a strict set of axiomatic rules, and thus aim to uncover causal relationships.

Positivism is often critiqued due to concerns surrounding both its ontological and epistemological assumptions (Lincoln & Guba 1985), as a strict focus on linear causality can lead to misguided interpretations when dealing with systems that display nonlinear behaviour. As social systems—the focus of the thesis—often display complex relationships amongst numerous components, it is argued that a positivist approach may not appropriately explore the complexity espoused by the research questions.

In contrast, a constructivist inquiry proposes a different philosophical paradigm to positivistic research. Originally referred to as *naturalistic inquiry* (Lincoln & Guba 1985), constructivism carries a number of ontological and epistemological assumptions concerning the basis of reality. Namely, constructivism centres around the premise that mental models are constructed rather than acquired,

and thus a holistic stance is adopted whereby objects and events are derived from their relational context (Overton 2011). Lincoln and Guba (1985, p. 37) list five key axiomatic assumptions concerning this paradigm, which are discussed in Table 3.1.

Axiom	Framing within Thesis
(1) Realities are multiple, constructed and holistic.	Individuals will have their own experience of disruptions based upon their role within a specific system.
(2) Knower and known are interactive, inseparable	As objectivity, in its purest form, is unattainable, special consideration needs to be made to address investigator bias
(3) Only time-and context-bound working hypotheses (idiographic statements) are possible.	Conclusions derived from results are limited towards contextual limitations, and thus obtaining a universal 'truth', or nomothetic generalisation is not possible.
(4) All entities are in a state of mutual simultaneous shaping, so that it is impossible to distinguish causes from effects.	Complex systems are inherently subject to forces that inhibit strict causality. Although individuals may understand actions as leading to outcomes, systemic factors may inhibit or support this process
(5) Inquiry is value-bound.	The outcomes and conclusions are influenced by both the theoretical and paradigmatic approach undertaken within the thesis

Table 3.1 Constructivism Axioms

Acknowledging the methodological issues surrounding measurement and risk perceptions discussed in the previous chapter, it is argued that adopting this paradigm allows for an additional perspective on risk behaviours and outcomes to

be undertaken. This allows for the thesis to generate a unique methodological contribution to the ongoing discussion of risk perceptions and action.

Ontological Assumptions: As with any research paradigm, several assumptions underpin the ontological, epistemological and methodological frameworks. The most commonly derived statement regarding ontology within constructivism is the idea of multiple interpretations, or constructions, of reality (Bowen 2008; Guba & Lincoln 1994; Lincoln & Guba 1985). Such a position renders the idea of a *true,* single reality as difficult to prescribe, instead relying on individual constructions and perceptions (Lincoln & Guba 1985). Such constructions are the product of individual determinations of a phenomena based upon contextual factors including environment and temporal reality (Schwandt 1994). Therefore, individuals may experience disruptions in different manners due to both interpersonal and system characteristics.

Epistemological Assumptions: the core basis of epistemology under constructivism is that the inquirer and object of inquiry are intertwined (Lincoln & Guba 1985), whereby findings are "created" within the investigation (Guba & Lincoln 1994, p. 109). Van der Pijl (2009, p. 107) discusses this as the *interpretive* method, which uses "introspection, empathy, to arrive at a reconstructed understanding of the reasons behind an actor's actions or utterances." An important consideration (as briefly described in Table 3.1) is that due to the interconnection between the investigator

and objects of investigation, potential biases need to be addressed, which are discussed in section 3.41.

Methodological Assumptions: Guba and Lincoln (1994) argue that a constructivist paradigm leads to a hermeneutical (or dialectic) approach towards methodology. Hermeneutics is broadly referred to as a manner of interpreting meaning from text, historically linked with biblical analysis (Byrne 2001). Hermeneutics can be expressed as a collection of interpretative scientific approaches rather than one single paradigm (Patterson & Williams 2002). Accordingly there has been a rich history of philosophical discourse surrounding hermeneutics, leading to the emergence of concepts such as phenomenology(Heidegger 1996; Husserl 1960).

Rather than attempting to contribute to the wider philosophical discussions of hermeneutics, the thesis takes an overarching approach towards this methodology, emphasising the role of interpretation within scientific endeavours. As discussed by Van der Pijl (2009, p. 96):

> In the case of hermeneutics, we may make informed inferences about the inner drives of the people, communities, cultures that we study. Since we are observing human beings who are, like us, intuitive, experiential, impressionable, etc., we may not be able to penetrate the 'object' entirely; yet as fellow humans, they must be expected to be motivated by driving forces which we can recognise or reconstruct if we properly assimilate their particular starting point, their mindset, and culture.

Rather than assume absolute relativism, hermeneutics acknowledges the existence of environmental structure that is subject to variance amongst individual interpretations and interactions (Patterson & Williams 2002). Therefore, in the context of the thesis, the individual framing of a disruption matters; as the individual interpretation and interactions with those events vary due to both individual and environmental factors. The emergence of hermeneutics within the thesis becomes evident within the transcription and coding process; as inferences are drawn from the transcripts based upon the author's interpretation of the interviewees' discussion.

3.1.1 Hermeneutics and Abductive Research

In terms of research methods, hermeneutics takes a middle-ground approach between a deduction-led conceptual framework—whereby inference is drawn from a rules-based framework and empirical cases (Niiniluoto 1999)—and an inductive-approach, whereby phenomena is viewed openly without any preconceptions or overarching theoretical framework (Braun & Clarke 2006; Patterson & Williams 2002).

This thesis follows a hybrid model of theoretical abduction (as described by Dubois & Gadde 2002; Kovács & Spens 2005; Niiniluoto 1999; Richardson & Kramer 2006). Abductive reasoning follows a line of logic that inference can be drawn from both theoretical assumptions and emergent themes within a set of data (in this case, semi-structure interviews). Such a premise deviates from traditional deductive research (that relies on a strict set of axiomatic hypotheses to test) and grounded-theory based inductive research, despite the latter's prevalence within constructivist research (Lincoln & Guba 1985). The utility of abductive research lies it its ability to discover new phenomena (Dubois & Gadde 2002) through incorporating aspects of both deductive and inductive reasoning.

Although studies incorporate both deductive and inductive phases without explicitly referring to abduction (e.g. Wieland & Wallenburg 2012), the uses the phrase abduction to refer to a hybrid logic of reasoning encompassing both deductive and abductive approaches (utilising a framework proposed in Kovács & Spens 2005).

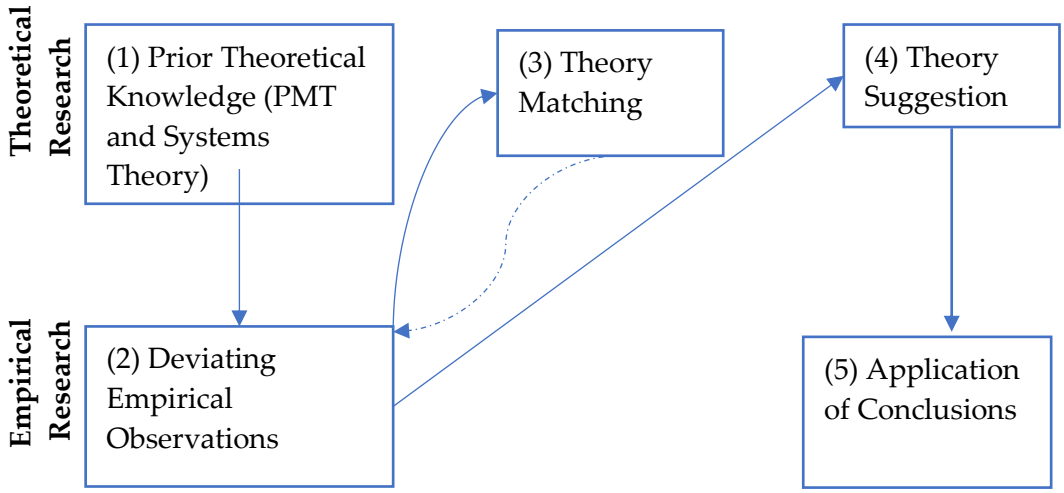

Figure 3.1 Abductive Research Approach (adapted from Kovács and Spens 2005, p.139)

As the previous chapter outlined the literature surrounding two seemingly separate academic fields, the thesis explores data that uses both the main theoretical paradigms (PMT and systems theory) from an abductive perspective. The data analysis seeks to answer the research questions from these two perspectives and the methods are devised in such a way to allow for emergent themes to be discussed as per Figure 4.1

3.2 Semi-Structured Interviews and the 'Critical Incident Technique'

Interviews represent a powerful data collection tool due to their ability to capture individual constructs of the world (McCracken 1988). Furthermore they allow for exploration of subjective experiences (Denzin & Lincoln 2011) and a substantial degree of flexibility towards understanding different levels of meaning (Cassell & Symon 2004). Interviews can be structured—with a strict set of questions with limited response variation (Fontana & Frey 1994)—or adopt a semi-structured

approach, whereby questions are open to allow for new ideas and concepts to be captured (Hennink et al. 2010).

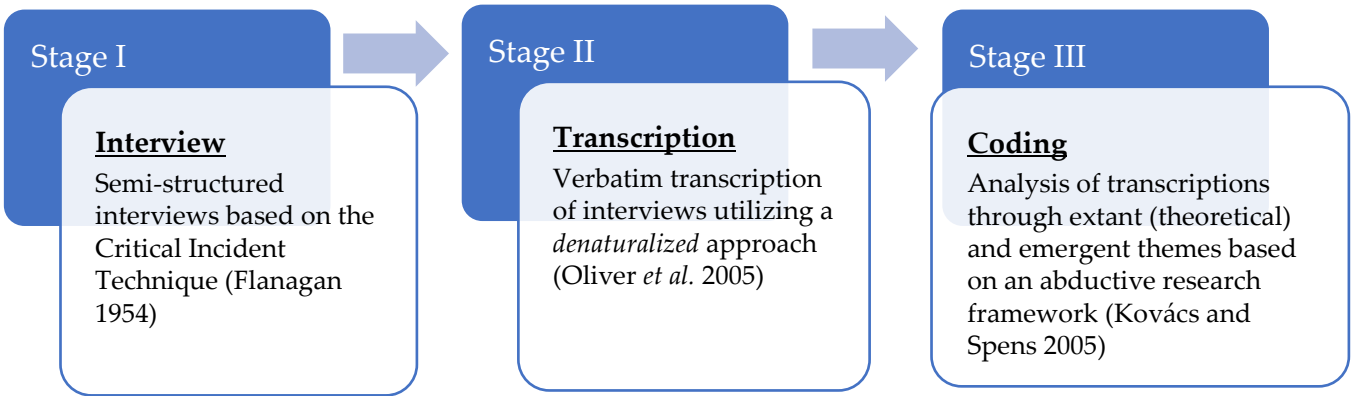

Figure 3.2 Three-Stage Research Design

In order to provide accuracy towards the research instruments, an established interview framework is utilised to enhance the elicitation of content from the interviews. The Critical Incident Technique (CIT), first proposed by Flanagan (1954), explores scenarios that are perceived to have had a positive or negative impact on a system (Ronan & Latham 1974), or significantly detract from established goals (Bitner et al. 1990). Practically this involves the development of questions guided towards measuring the outcome of actions in relation to 'critical' events that have previously occurred (Craighead et al. 2007). Within the context of the thesis, critical events are synonymous with disruptions.

CIT has been applied interdisciplinary (as discussed in Butterfield et al. 2005) due to adaptability towards any scenario (Flanagan 1954). CIT is operationalised as semi-structured interviews asking respondents to reflect on a particular event and the degree to which it was handled either well or poorly (Craighead et al. 2007). By employing open-ended questions based on experience of historic disruptions CIT

can be used to measure antecedent variables, choices and the system response to disruptions. Therefore, questions are designed across the stages reflected in the research framework discussed later in this chapter.

The use of CIT further serves as an important delineation between historical and new risks. Historical risks are those that have occurred in the past and can be recalled sufficiently enough to form a data set, whereas new risks are those that have not been observed previously (Wilson & Crouch 2001). However, this runs the risk of attribution bias for 'Black Swan' events, as individuals may construct different appraisals of an event with the benefit of hindsight (Taleb 2007). To limit the magnitude of this risk, individuals were informed at the start of the interview to recall their appraisals and actions at the time of the event as accurately as possible, rather than apply post-event hindsight.

3.3 Interview Transcription

The first stage of data analysis involves the transcription of the interviews. The interview transcription process identified several considerations that needed to be made. Firstly, the issue of verbatim versus non-verbatim transcription had to be addressed in order to ensure consistency amongst the individual transcribed interviews. Secondly, interpretive biases need to be outlined and correct protocols established to avoid biases negative influencing the information elicited from the interviews.

3.3.1 Transcription Approaches

A key issue surrounding the transcription of qualitative research is the interpretation of data and 'data reliability' (Poland 1995). Verbatim transcriptions (whereby interviews are transcribed as close to the recorded interview as possible) is often viewed as a means of addressing transcription error; 'the discrepancy between the written record (transcript) and the audiotape recording of the research interview upon which it is based" (Poland 1995, p. 291).

However, the decision to use verbatim or non-verbatim transcription of the interviews comes at a trade-off (Halcomb & Davidson 2006). Although verbatim transcription of qualitative research is viewed as an important method towards data accuracy (Easton et al. 2000; Hennink et al. 2010; Oliver et al. 2005), the transcription process itself is susceptible to transcription inaccuracy. Transcriptions of interviews, regardless of whether they are verbatim, only capture the audio context at a given point in time; therefore, negating any non-verbal communication such as physical observation (shuffling, facial expressions). Adopting a perspective that no singular method can claim authoritative truth about a phenomena (Richardson 1993), applying a strict verbatim approach to transcription may only be a tacit assumption of true data representation (Poland 1995). Additionally, transcriptions may only be as strong as the interpretation and transcription skills of the transcriber, with it being assumed that no transcription can be a 100% accurate representation of the interview (MacLean et al. 2004).

Transcription can be broadly classified as a continuum between two linguistic techniques; *naturalism* and *denaturalism*[9] (Oliver et al. 2005). The former incorporates all utterances as an important part of the transcription process, whereas the latter removes such idiosyncrasies; such as interviewee movements and conversation fillers (Oliver et al. 2005). The determination of where a research project fits within this continuum is guided by the theoretical and philosophical approach of the project. In projects where the focus is on *what* is being said (rather than *how*), a more denaturalised approach towards the transcription process may be utilised (Oliver et al. 2005).

As this thesis is focused around the implications of protective actions as deduced from the interview, rather than the linguistic constructions under which it was delivered (i.e. language and non-verbal communication), a denaturalised approach to transcription has been adopted.

3.3.2 Transcription Results

Transcriptions were conducted based on the criteria established in the previous chapter, with particularly idiosyncratic utterances not included in the transcript. Additionally, where needed, the transcribed sentence was slightly altered for clarity, without impacting the meaning of the sentence. Although this suggests the transcripts may not be a *pure* verbatim, the non-naturalistic approach towards the

[9] Not to be confused with a naturalistic research paradigm discussed in Section 4.1

transcription process does not necessitate the inclusion of idiosyncratic utterances within the transcript.

Furthermore, to ensure accuracy when there were particular words that were difficult to hear (due to either a lack of clarity spoken or environmental noises), the phrase "[INAUDIBLE]" was inserted into the transcript. However, it was discovered that this did not adversely impact the flow, or meaning, of any particular sentence.

Accordingly, the denaturalised approach has sought to produce the most accurate transcripts relevant towards the thesis. As discussed in Table 3.2 during situations where the interviewee uses one of the above omissions in such a manner that changes the meaning (i.e. sarcasm, or over-exaggerations), these were treated on a case-by-case basis to avoid drawing misinterpretations.

3.3.3 Interpretation Bias

Despite the careful construction of measurement techniques (through rigorous questions and verbatim transcription), words will always possess a degree of ambiguity (Fontana & Frey 1994). Interpretation of text is linked to the research paradigm (Denzin 1994), therefore a constructivist approach will, by nature, derive meanings and interpretations from the interview transcripts. However—as with all research methods—there is a risk of bias influencing interpretation.

Although it possesses a degree of ambiguity (Hammersley & Gomm 1997), bias is often linked with positivist assumptions about research design, particular with terminology such as "confirmation bias" and "error" (Roulston & Shelton 2015, p. 335). Within constructivist research, eliminating perceptions of bias is achieved through researchers recognising how 'voices' are constructed from text (Roulston & Shelton 2015). Furthermore, interpretation accuracy within constructivism can be ascertained through theoretical sampling, theory, inductive analysis and contextual interpretations (Denzin 1994). By utilising the abductive approach discussed in section 3.1.1, the results derived from interpretive text are cross-examined within both extant (i.e. theory derived from the literature review) and emergent (i.e. from other interviews) sources, therefore minimising the risk of interpretive bias.

3.4 Interview Analysis

3.4.1 Unit of Analysis and Definitional Contextualisation

As the thesis aims to explore the intersection of disruptions, individuals and systems several contextual definitions need to be clarified. The first of these is the central

point of the data analysis or the *unit of analysis*. The thesis adopts an activity-focus unit of analysis (Patton 2002) by having individual interviews reflect upon a single critical incident (i.e. disruption).

Furthermore, the previous chapter outlined a new of terms that possess definitional ambiguity within the literature. Therefore, the thesis operationalises the following phrases:

1) *Agency* as the perceived ability of an individual to undertake action within a system.
2) *Disruptions* as any event that can be perceived as impacting the performance of a system..
3) *Redundancy* is a type of strategy whereby more of the same work is added to alleviate the impact of a disruption.
4) *Flexibility* is a type of strategy where the individual and/or system will adapt and approach a disruption differently than current work.

Furthermore, the literature discussed in the previous chapters surrounding decision-theories provides a substantial list of seemingly separate (or at-times contradictory) terms such as choice, action, motivation and decision. The focus of the thesis is on the *action* undertaken, therefore the results and interviews focus on the actual path indiviuals undertake (i.e. the action they made).

3.4.2 Data Coding

The second stage of data analysis consists of coding the interview transcripts. Coding is often regarded as a core component of qualitative research (Hennink et al. 2010), broadly referring to an iterative process to map out emergent themes within a data set (i.e. interview transcripts). Such a process leads to the emergence of themes, that can exist at the manifest level (directly observable) or latent level (underlying the phenomenon) (Boyatzis 1998). Miles and Huberman (1994) propose 13 distinct tactics for coding, ranging from initial thematic identification to intervening variable identification and establishing theoretical validation. Other tactics include establishing a coding criterion (e.g. Barratt et al. 2011), which utilises questions as a means of identifying how individual data sets fit into a defined list of codes.

The thesis utilises an abductive approach to coding, whereby the first-level codes are based on the conceptual framework discussed in the following section, and the second-level coding dealing with emergent themes within the data (which are validated through extant literature explored in the previous chapter). The rationale behind moving away from a grounded-theory approach (despite its prominence within constructivist literature) is the lack of theoretical assumption. This rationale is based on two perspectives; the abundance of relevant, extant theory to derive interpretations from, and the risk of false inferences being drawn from the data due to the lack of theoretical knowledge. Therefore, the research uses codes derived from the literature to provide initial validity of inferences drawn.

Code	Description
System overview	Interviewee description of the system they are discussing and their role within it. This allows for demarcation of system boundaries to be established and an evaluation of their agency in the system.
System vulnerability	Components of the system that allowed the disruption to manifest itself in the first place.
Disruption occurrence	Descriptions of the disruption itself, including threat identification.
Threat Appraisal	Discussions of the perceived probability and magnitude of the disruption from the interviewees' standpoint.
Coping Appraisal	Description of choice-appraisal processes, including the evaluation of options and appraisals of self and response efficacies.
Choice Classification	The components of the choice itself, included whether it can be classified into various categories. Categories used included aided-analytic and non-aided analytic (Section 3.1), redundancy and flexibility (Section 3.61) and temporal dichotomy (Section 3.62)
Transient Response	The behaviour of the system during and after the disruption. These parts of the interviews aimed to uncover the relationship between protective choice and the system behaviour as a qualitative description of the performance variation over time)
System Outcome	This coding was primarily developed to analyse the outcome of the system, including whether the system can be classified as having survived or perished as a result of the disruption described.

Table 3.2 Overview of First Level Codes

It is also recognised that during the initial analysis stage, emergent themes may necessitate re-coding and the influence of researcher experienced gained from undertaking the interviews. Therefore, emergent codes are discussed in the first section of the following chapter.

3.5 Interview Structure and Sampling

In order to enhance validity of data the sampling has to be representative of a phenomena as a whole (Patterson & Williams 2002). Due to the thesis aims to providing theoretical contributions in terms of merging system theories with decision-making theories, it became important for the interviewee context to be universal, rather than focusing on one type of system (such as a specific organisational type) or disruption.

Accordingly, the research participants were sampled from professional and peer networks with the aim of providing a holistic perspective of risks and disruptions. Although this may seemingly influence the bias of participant selection, the main risk associated with the method is surrounding interpretation (as discussed in section 4.41), therefore any risk regarding participant selection has been deemed to be minimal. Furthermore, the risk of bias has been negated due to the sampling technical of purposeful sampling, whereby it is designed to be generic and therefore information-rich in terms of the purpose (Patton 2002). The overall generic approach to sampling—individual experiences of disruptions—allowed for a rich array of data

to be collected as a more generalisable approach towards disruptions, systems and individuals was undertaken.

The interviews ranged in length from 15 minutes to 1 hour. There was often a period of reflection at the start of the interviews where the interviewee was determining the disruption of which they would discuss. The reason behind this approach—rather than sending the interview questions at an earlier point in time—was to capture the spontaneity of recalling events on the basis that it might allow for the events to be explained in a more exploratory sense. Thus, the risk of interviewees developing hindsight-driven rationales—common for unexpected events (Taleb 2007)—may be minimised through this approach.

After the disruption was identified the interview followed a series of questions based on the Critical Incident Technique, capturing the theoretical frameworks identified within the literature review chapters. A list of pre-determined questions was used (see Appendix A), and the exploratory approach of the research allowed for the questions to be shaped in accordance with the context being discussed.

The interviews typically followed a pattern of emergent design; whereby questions were adapted for contextual circumstances. For example, the following questions in Appendix A:

> Why was protective action needed to respond to that disruption?
>
> Why did you choose to do (or not do) that particular action?

Below is an example of an emergent question, demonstrating its adaption towards the context of a particular interview (taken from INT6):

> When you started detecting there's a potential for a delay to occur, what did you, as consultants to this supplier, end up doing?

As demonstrated above, during the interviews the questions asked began to differentiate themselves from the established questions in Appendix A. This in turn allowed for a more exploratory approach to the interviews to be undertaken, with the main interview resources (namely the questions in Appendix A and the conceptual framework discussed in the previous chapter) supporting this process.

3.6 Data Saturation[10] and Research Evaluation

3.6.1 Data Saturation

Often linked to the epistemological framework of a research project (O'reilly & Parker 2013), data saturation is the subjective point whereby data begins to produce diminishing returns (Bowen 2008). Data saturation is often a point of contention within research (O'reilly & Parker 2013), especially with regard to questions

[10] As the thesis is qualitative, phrases such as 'data', 'validity', 'significant' are avoided due to their connotations with quantitative research methods. Accordingly, phrases such as 'interviews' and 'transcripts' are used synonymously referring to the information elicited from the semi-structured interviews.

concerning sample sizes (Fusch & Ness 2015). Furthermore, inconsistencies surrounding the use of data saturation renders the idea specific to the methodology (Walker 2012). In order to establish a rigorous and justifiable saturation protocol for this thesis, there are a few common points that can be ascertained and applied towards the interview process.

Within qualitative research that emphasises the coding of data, points of saturation include the lack of new themes and codes emerging from the data, and also the ability to replicate the study within other methodological frameworks (Fusch & Ness 2015; Guest et al. 2006). Depending upon the nature of inquiry, saturation may be determined by adequacy rather than size (Bowen 2008). However, Fusch and Ness (2015) argues that obtaining both *rich* (in quality) and *thick* (in quantity) can assist in determining data saturation. In the context of the thesis, the following guidance proposed by Fusch and Ness (2015, p. 1413) is followed:

> Data saturation is reached when there is enough information to replicate the study (O'Reilly & Parker, 2012; Walker, 2012), when the ability to obtain additional [no] new information has been attained (Guest et al., 2006), and when further coding is no longer feasible (Guest et al., 2006).

Empirically testing the first point regarding replicability of the study falls outside the scope of the thesis, however future research may triangulate the findings with other research methodologies. Therefore, the second and third points serve as the primary influence on the saturation protocol for the thesis; a subjective

determination that subsequent interviews will not produce any new information based upon the scope of the research.

Rather than apply a numerical sample size to aim towards, the thesis undertakes interviews until two important distinctions are made. First, the information is adequate to address the conceptual frameworks and research questions, and secondly when a point of diminishing returns has been determined. Therefore, the point of diminishing returns—where no new themes emerged—was determined after a subsequent number of interviews did not provide any new themes than both (1) those established in the conceptual framework, and (2) the second-level codes described below. The lack of consensus and guidance drawn from the reviewed literature surrounding data saturation within qualitative research led to the subjective protocol described above being followed. The above protocol is tested against several key facets of qualitative research evaluation.

3.6.2 Research Evaluation

The seemingly vague interpretation of qualitative research has enabled results to be subject to critique by positivist researchers (Shenton 2004). Accordingly a number of qualitative researchers (such as Lincoln & Guba 1985; Marshall & Rossman 1989; Shenton 2004) have provided guidance to ensure rigour has been utilised within qualitative studies utilising common quantitative approachs such as *credibility, transferability, dependability* and *confirmability.* The definition and evaluation of these within the thesis are provided in the following table.

Concept	Definition	Evaluation within Thesis
Credibility	Marshall and Rossman (1989, p. 145) defines the goal of credibility as "to demonstrate that the inquiry was conducted in such a a manner as to ensure that the subject was accurately identified and described."	The thesis satisfies a number of the metrics for internal validity proposed by Shenton (2004), namely the adoption of established research methods (through the critical incident technique), the development of early familiarity with the culture of participants through the sourcing of individuals from extant peer and professional networks and triangulation through the use of multiple informants (thus allowing a wider spectrum of disruptions to be collected).
Transferability	Transferability, or external validity refers to generalisability of findings towards other contexts (Marshall & Rossman 1989).	By adopting a sampling approach that led to interviews with individuals across a wide range of systems, thus leading to a wide range of disruptions as units of analysis, the results and subsequent discussion can be used in a more general sense of understanding risk and risk management behaviour.
Dependability	Dependability refers to the individual account of "changing conditions in the phenomenon chosen for study as well as changes in the design created by increasingly refined understanding of the setting" (Marshall & Rossman 1989, pp. 146-147)	The previous sections of the chapter provide detail about the design of the study, which enables future researchers to potentially repeat the work in a similar fashion as done within the thesis (Shenton 2004)
Confirmability	Confirmability refers to the objectivity of the researcher and whether the findings of the study can be captured by another research	As the thesis utilised an abductive research approach with an emphasis on extant literature and theory, the results are linked back to well-established concepts within the various literature streams evaluated in the previous chapter. However, Marshall and Rossman (1989) argue that qualitative research is not designed to be replicable due to naturalistic interpretations of the world. By utilising an abductive approach informed by the literature—and triangulating the data points across a wide spectrum of disruptions—the thesis demonstrates a degree of confirmability.

Table 3.3 Research Evaluation

Triangulation: As discussed in the above table, triangulation can be used to enhance the trustworthiness, or overall validity, of the thesis. Regardless of the sample size, data triangulation allows for the validity of interpretations to be strengthened. Commonly used within qualitative studies, Triangulation refers to the utilisation of two or more strategies to allow for a holistic understanding of phenomena to be established (Thurmond 2001), inclusive of data triangulation (Barratt et al. 2011), investigator triangulation (Eisenhardt 1989), multiple triangulation, theory triangulation and methodological triangulation (Jick 1979). Shenton (2004, p. 66) discusses the use of multiple informants (i.e. data points) as a way of achieving triangulation:

> Here individual viewpoints and experiences can be verified against others and, ultimately, a rich picture of the attitudes, needs or behaviour of those under scrutiny may be constructed based on the contributions of a range of people.

Contextualised within the thesis, triangulation takes the form of both *interdisciplinary triangulation* through the use of multiple disciplines of the literature to inform the abductive approach (Janesick 1994), and triangulation of the findings across various data points. This supports saturation, as the previously mentioned criteria of diminishing returns can be supported by the findings being triangulate across other disruptions.

3.7 Conclusion

This chapter has explored the paradigmatic assumptions and subsequent methodological and method-driven practises undertaken in the thesis. Adopting a constructivist paradigm shifts away from traditional positivist paradigms through the acknowledgement of the existence of multiple realities based upon individual perspective and context. The utilisation of a constructivist approach towards understanding protective actions within disruptions offers a unique interpretation of this research problem and adopting an abductive approach towards analysis furthers the theoretical validation of the discussion points in the latter chapters of the thesis.

By utilising an abductive research approach; whereby inferences from the interviews are drawn from both extant (from the literature) and emergent (from the interviews) themes, both theoretically-established and new concepts are explored concurrently within the interviews. This abductive approach allows for the major source of bias within this research method—misguided inferences drawn from interpretations—to be minimised via a pre-established theoretical framework.

Thus accordingly, an interviewee-led research method informed by the Critical Incident Technique allows for a pragmatic process of data collection to be undertaken. The data collection and analysis include both denaturalised transcription and first-level (conceptual framework) and second-level (emergent) coding, with interpretations drawn from the interview transcripts seeking to provide

a unique understanding of individual decision-making within systems facing disruptions.

Chapter 4 Results

This chapter outlines the results obtained from semi-structured interviews that seek to address the research questions established in Chapter 1[11]. This chapter is split into two parts; with part one depicting the interview and coding processes, and the second part describing the major themes emergent from the interviews.

The first section details the interview process describing how questions were adapted towards individual contexts. Following from this, an overview of the transcription process and the interviews is provided, depicting the individual contexts that were described within the interviews. This is followed by a discussion of data saturation, and the emergence of second-level codes within the interviews.

The second part of the chapter analyses the results ascertained from the interviews. This section starts with an analysis of individual framings, and how the positioning of an individual with reference to various systems influences the perception of agency. Following from this, the latter half of the chapter is split into various sections based upon the conceptual framework discussed in the previous chapter, with both the first-level codes and emergent codes being merged across three key areas based on the triadic interaction between individual, system and disruption discussed in Scheibe and Blackhurst (2017).

[11] The interviews were conducted with approval from the University of Wollongong's Human Research Ethics Committee (HREC), protocol number 2017/061.

The first part of the analysis describes the system threat profiles and disruption occurrence, outlying the various disruption types described within the interviews and their common characteristics. This is followed by the results on both threat and coping appraisals, discussing the variation amongst individual appraisal with reference to the type of disruption and extent detection mechanisms.

Thirdly, the various dimensions that inform choice classification are discussed, highlighting the temporal scope (i.e. proactive/reactive), whether the choice was a redundancy or flexibility, and the *rapidity* (i.e. 'fast' or 'slow' thinking). This leads into the final stage of the analysis, discussing the various system responses, and the interplay between the choices and the type of system responses. The chapter concludes by summarising the results and providing the framework for the discussion in Chapter 5.

4.1 Data Point Overview

Table 4.1 provides an overview of the data points with disruptions being the central unit of analysis. The interviews have been classified across several dimensions; their unique disruption identifying code (e.g. D1), their relevant interview (e.g. INT1, as some interviews discussed multiple, independent disruptions) the system type (e.g. for organisations the type of industry), and the individuals role within the system (also referred to as decision-maker positioning) .

The system and decision-maker positioning seek to provide an overview of the interviewee characteristics, firstly by looking at the system (or systems, depending upon the number of events they discussed) and their agency within those systems. Within several interviews, multiple disruptions and multiple system were discussed. The disruption dimension provides a basic overview of the disruptions that have been discussed throughout the course of the interview.

Interview Framing Limitations: As discussed in Chapter 3, the interviews could flow according to the trajectory the interviewee wished to discuss in order to allow emergent themes to be uncovered. Although the questions were structured around CIT (as a means of evaluating an event in its entirety), on occasion the interviewee would instead offer insight into generalisable system behaviour against disruptions whereby the transient response of the disruption (in terms of post, during and after temporality) became difficult to ascertain during the analysis stage. Although this deviated from the aims of the interviews discussed in the previous chapter, these interviews offered at times a vast array of system behaviours with regards to disruptions that is traded-off with a clear narrative of a disruption that was discussed in other interviews There are identified within Table 4.1 as two distinct interview types:

Disruption-centric: whereby the transcript offered a clear narrative of the central unit of analysis. This was the case for the vast majority of the data points outlined in Table 4.1.

System-centric: whereby the narrative of the interview focused on a holistic overview of the system and the transient response of the unit of analysis was difficult to analysis.

Table 4.1 lists the following points of information:

1. Disruption Code: the numerical code of the disruption designated sequentially.
2. Interview Number: the relevant interview from which the disruption code comes from.
3. Interview Type: the classification of an interview as either *disruption-centric* or *system-centric.*
4. Disruption Overview: a brief description of the disruption contextualised within the interview.
5. System Description: the type of system and (if relevant) industry.
6. Individual positioning/role: description of the individual's position within the system.

Disruption Code	Interview Number	Interview Type	System Description	Disruption Overview	Individual Positioning/Role
D1	1	Disruption-centric	Healthcare (hospital) services	Individual detailing their experiences of a family member requiring expedited surgery.	Individual was involved with decision-maker about the family member's health, but services were provided by hospital staff.
D2	2	Disruption-centric	Organisation specialising in services for at-risk youth	Weekly outreach program in the community where team responded to complaints about underage drinking in a local park.	Front-line staff worker directly engaging with clients in charge of small 2-person team
D3	2	Disruption-centric	*As above*	Similar outreach program as above but the disruption centred around threats of violence between two groups of youths.	*As above*
D4	3	Disruption-centric	Small-to-medium sized business specialising in table-top board games	Periodically run event with a higher-than-expected retainment of clients	Manager/owner of business
D5	3	Disruption-centric	*As above*	Other worker in a two-person team injured themselves, rendering them unavailable for a weekend	*As above*

Disruption Code	Interview Number	Interview Type	System Description	Disruption Overview	Individual Positioning/Role
				shift that was expected to have high levels of demand	
D6	3	Disruption-centric	*As above*	Periodic event that had a much lower than expected turn-out (i.e. demand rate).	*As above*
D7	4	Disruption-centric	Café specialising on coffee	Shortage of core product (milk) that could render the business unable to remain open.	Front-line staff worker
D8	4	Disruption-centric	*As above*	Unexpected surge in customers arriving in store due to an unanticipated local carnival.	*As above*
D9	5	Disruption-centric	Private university	Legislative changes introduced by national government that required all courses to be reconfigured.	Front-line worker involved in student services
D10	5	Disruption-centric	*As above*	IT glitch resulting in many student records being corrupted beyond repair.	*As above*

Disruption Code	Interview Number	Interview Type	System Description	Disruption Overview	Individual Positioning/Role
D11	6	Disruption-centric	Transport engineering consultancy firm	Supplier contracted to provide a new fleet of trains failed to achieve performance targets by a pre-defined date.	Engineering manager of a group of engineers.
D12	6	Disruption-centric	*As above*	Delays in decision-making by external stakeholders (local government) that delayed anticipated project execution.	*As above*
D13	7	Disruption-centric	Power tool company	Sale on a power-tool set that led to immediate stockouts both in-store and in supplier warehouses.	Front-line customer service worker
D14	7	Disruption-centric	Stationery and office supplier	Several workers in similar positions to the interviewee leaving within a rapid time-period.	*As above*
D15	8	Disruption-centric	Share-trading arm of a large multinational bank	Periodically run marketing campaign was more successful than anticipated within reoccurring errors causing a feedback of work-to-be-done.	Customer-facing worker within the team dealing with international share options.

Disruption Code	Interview Number	Interview Type	System Description	Disruption Overview	Individual Positioning/Role
D16	8	Disruption-centric	*As above*	External electronic infrastructure (the Australian Stock Exchange or ASX) system glitched and went offline.	*As above*
D17	8	Disruption-centric	*As above*	Local electronic infrastructure (website for customers to engage in buying and selling shares) unexpectedly went offline.	*As above*
D18	9	Disruption-centric	Clothing store owned by an international organisation	Wider company takeover resulting in a change to front-end operations.	Front-line customer service worker
D19	9	Disruption-centric	*As above*	Construction worker within the shopping mall that the store is located in leading to customers being unable to locate the store.	*As above*
D20	9	System-centric	*As above*	General discussion about stock-issues facing the organisation.	*As above*

Disruption Code	Interview Number	Interview Type	System Description	Disruption Overview	Individual Positioning/Role
D21	10	Disruption-centric	Liquor store	Store was demerged from parent company that had provided products and services.	Front-line customer service worker.
D22	11	System-Centric	Disability service provider	General discussion about how the individual and other actors within the system deal with client behaviours.	Front-line staff worker directly engaging with clients.
D23	12	System-centric	Plumbing business with services ranging from small residential to large-style commercial.	General observations about dealing with disruptions to project time impacting achieving target goals.	Senior plumber overseeing a number of full-time and subcontracted workers.
D24	12	Disruption-centric	*As above*	Time-critical supply issue during a routine project.	*As above*
D25	13	Disruption-centric	Large multinational freight forwarding company	Unique product size and type to be shipped that made finding an appropriate logistics provider difficult to ascertain.	Worker overseeing various clients who have accounts with the organisation.
D26	13	Disruption-centric	*As above*	Inability to find a logistics provider to ship a client's product due to the hazardous	*As above*

Disruption Code	Interview Number	Interview Type	System Description	Disruption Overview	Individual Positioning/Role
				nature of the item to be shipped.	
D27	14	Disruption-centric	Individual taking their overseas parents on a holiday.	Distance and time impacting the ability to reach specific locations.	Individual oversaw decision-making for the holiday due to their in-country experience.
D28	15	Disruption-centric	Medium sized restaurant.	Core piece of equipment failing before during pre-service preparation.	Head chef in charge of all kitchen operations.
D29	16	Disruption-centric	Property Valuation Company	Last-minute request for a large series of valuations for a client that other property valuation companies had refused to undertake.	Individual tasked with organising property evaluations.

Table 4.1 Overview of Interviews

4.2 Second-Level Codes

During the analysis of the first-level codes described in the previous chapter, emergent themes began to emerge from analysis of the extant codes. In ensure to explore these emergent codes they were retrospectively added towards the analysis frameworks of previous interviews, although there were often cases where there were no major themes concerning these codes ascertained from an interview.

Code Name	Definition
Side Effect	Unintended consequences that arise from the choice enacted.
Speed of Onset	The degree of rapidity associated with a disruption.
Inherent Disruptions	System characteristics that result in disruptions being a central part of the system.
Disruption Construction	Individual constructions of what constitutes a disruption.
Structured versus Unstructured procedure	The degree of structure (i.e. procedural or ad-hoc) that led to a choice being undertaken.
Goal-based outcome	Contextualisation of system survival/failure whereby this binary is defined upon whether the system can reach a stated goal.
Feedback	The role of experience (or emergent events) influencing the utility of a choice.
Dynamic Disruptions	Disruptions being multi-faceted.

Loss Trade-Off	Utility of a choice expressed as a zero-sum, or where one type of loss is better than a real (or imagined) alternative.
Demand Patterns	Demand follows various types of patterns that can lead to a disruption occurring.
Hybrid Strategy	Types of choices that do not exist as a binary of either redundancy or flexibility.

Table 4.2 Second-Level Codes

The second-level codes, which were emergent themes throughout the data analysis, can be further refined into a series of phenomena based on the triad of disruptions, choices and system. These

4.3 Aggregation of Results

The next section of the chapter outlines main results ascertained from the interviews. These are split into several sections reflecting the conceptual framework in the previous chapter. The first section provides a brief aggregation of the results followed by a discussed surrounding the role that framing played within individual agency.

Following from this, the results are presented across a number of sections as follows: (1) disruption characteristics, (2) threat and coping appraisals, (3) choice types and (4) system response and outcome.

Table 4.3 presents an aggregate count of the phenomenon derived from both Table 4.1 and the incorporation of the emergent codes within the framework discussed in the previous chapter.

Phenomena	Count	Data Points
Interview Type		
Disruption-centric	26	
System-centric	3	
	29	
Individual Role		
Customer/Client Facing	20	
Managerial	9	
	29	
Disruption Characteristics		
Demand-based	10	D1,D2,D3,D4,D8, D10, D12, D13, D15, D19
Supply-side	7	D5,D6,D7, D14, D24, D25, D26
System Restructuring	3	D9, D18, D21
Goal-Based	6	D11, D16, D17, D27, D28, D29
	26[12]	
Choice Types		
Proactive	6	D5,D7, D9, D11, D24, D27
Reactive	20	D1,D2,D3,D4,D6,D8, D10, D12, D15, D6, D17, D18, D19, D21, D25, D26, D28, D29, D13, D14
	26	
Redundancy	13	D1,D5,D6,D7, D10, D13, D14, D17, D16, D19, D27, D25, D26
Flexibility	13	D2,D3,D4,D8, D9, D11, D12, D15, D18, D24, D28, D29, D21
	26	
Slow Action	11	D5, D9, D11, D15, D18, D20, D24, D25, D26, D28, D29
Fast Action	15	D1,D2,D3,D4,D6,D7,D8, D10, D12, D13, D14, D16, D17, D19, D27
	26	
System Behavioural Type		
Responsive Return	14	D2,D3,D6,D7, D9, D11, D12, D15, D21, D24, D27, D28, D29, D18
Disruption Dissipation	8	D4,D5,D8, D10, D13, D14, D16, D17
System component/goal failure	4	D1, D25, D26, D19
	26	

[12] The three data-points that were system-centric (D20, D22, D23) have been excluded from the analysis with respect to the aggregate count as they do not describe a disruption that can be measured across a temporal time horizon.

Table 4.3 Aggregate of Results

4.3.1 Individual Framing

A theme that appeared early within the interviews was the idea of individual framing of a disruption, and thus the framing of the system itself. The interviewees talked about their experience within a given system; depending upon the scope the individual's system could be expressed as a sub-component of a wider system—for example D18 and D21 that discussed their direct system being either merged or demerged with a larger organisation—in a similar vein towards system hierarchies and boundaries as discussed in chapter 2:

> It's [the company leading the merger] a big company, so what they do is they just turn over companies that aren't doing well, so they buy them then somehow just turn it around, make sure they do better. So that's what they've done with us [D18].

> I'm attached to [parent company] but they've decided they're going to separate [parent company] and [individual's company]. So we're classified as standalone stores now. So, whereas we used to be managed by a supervisor from the [parent company] at night-time when all the managers are gone we now, we run ourselves[D21].

Furthermore, the substantial variation between interviewees may be linked to their respective positioning (as agents within one system but part of an overarching suprasystem). This in turn lead to variation in the identification of established risk-mitigation procedures[13]. This suggests that:

(1) The interviewees were not in a role within the system tasked with developed risk-mitigation strategies,
(2) The system did not possess any overarching risk mitigation strategy,
(3) The risk-mitigation strategy was not effectively communicated to other parts of the system,
(4) The system was designed for reactive responses to disruptions, or the reactive strategies possessed greater utility

Although the above points suggest that positioning and framing directly influences disruption perceptions, several other factors played similar roles in influencing choice. As systems are subject to hierarchies related to sub and

[13] In other words, proactive procedures to be enacted in the event of a particular disruption.

supra systems (Kast & Rosenzweig 1972), disruptions may only be visible to certain parts of a total system.

For example, as an individual whose role is in student services, the positioning of the individual within D10 is not going to be privy towards issues that arise in the IT department, however they are impacted by the magnitude of the disruption ("I was in the customer service side of it, so my actions was mainly dealing with cranky students").Therefore, the existence of relationships between the focal system (i.e. the one described in the interviews) and other peripheral systems—as well as an individual's bounded rationality (Simon 1972)—plays an important role in framing. This in turn will contextualised an individual's efficacy, as they may be limited in how they can respond to a disruption.

4.4 Disruption Characteristics

The systems were vulnerable to a wide variety of disruptions unique to each system.

The vulnerability of systems towards certain disruptions was closely linked to the behaviour of system components. For example, some systems faced disruptions arising from IT problems, such asD10, D16 and D17 which described large organisations with a reliance on substantial IT infrastructure as part of their day-to-day operations:

> So this was an issue with the ASX [Australian Stock Exchange] itself, but being the broker, people try to put orders through the system they come to us first. [D16]

This can be viewed in contrast to other systems that may not possess such a strong reliance on critical IT systems, such as the café described in D7/D8 or the youth/disability service organisations in D2/D3 and D22 respectively.

Other systems were designed around goals associated with dealing with disruptive behaviours, notably the two incidents around youth services (D2/D3) and the interview on disability services. D22 further clarifies this point:

> We've got a lot of clients where they have high [risk] behaviours, where they'll just starting hitting, kicking, biting, scratching. So once that sort of starts off, you've got to try and calm them down, go through a process sort of thing, but if they don't calm down eventually it gets to a point where you…[request external assistance]

As the system inherently deals with disruptive behaviours—which can be viewed as disruptive events—the above quote suggests both an appraisal of the threat associated with disruptive behaviour, but also an appraisal of the individual's ability to cope with the disruption; both as inherent parts of the system. Accordingly, the disruption profile was determined by the structure of a system and its components.

The varation amongst disruptions captured in Table 4.1 offers insight into several generalizable dimensions.

4.4.1 Demand-Based Disruptions

Demand based, or downstream disruptions[14] were observed to be emerged from individuals entering into a system (most commonly expressed as demand for a particular product or service). This was observed across the following four patterns: *surge, steady increase, constant* and *slowdown*. The observation of demand surges was expected as these are a common type of disruption, particularly within the context of emergencies (Roni et al. 2016). However, the other three demand patterns can be analysed as being reflective of the system's robustness levels rather than a unique demand pattern.

Demand surges were observed as a sudden, rapid increase in demand for a product or service. Several disruptions emulated this behaviour, notably a rapid increase in people entering a coffee shop (D8), a surge in customers seeking to purchase a heavily discount toolkit (D13), and a rapid increase in customers seeking a marketed financial product (D15).

[14] Utilising the phrase downstream/upstream as described by Mentzer et al. (2001)

> So people turned up from this carnival completely unexpected, and we ended up picking up on it after a while like "shit, you're all coming from the same place".[D8]

> It was only like, 200 bucks (sic) which is unreal for that type of equipment. And all the competitors ran out, the franchise, not the franchise the supplier ran out as well and they were backordering to like June this year. So whatever was on the shelf, that was it . [D13]

> So we were perceiving probably between two hundred new clients, maybe 150 clients per week. That was probably, half of what we actually, or probably double was we actually got, we were getting like 400 people a week, 100 new applications in per day. [D15]

As mentioned in the above paragraph demand surges are a common example of disruptions as they lead to an immediate overwhelming of extant robustness. An interesting caveat towards the understanding of demand surges was this it also captured scenarios whereby there is an immediate need for action (e.g. D1, where the individual's relative immediately required intervention in the form of surgery. Within this context, the surge was not a numerical surge but rather the magnitude of the disruption occurring immediately overwhelmed robustness. Therefore, within these types of scenarios a surge does not

necessarily necessitate a numerical surge, but in fact a transition from a system not needing a service and suddenly needing one. Accordingly, it can be argued that demand surges can additionally be reconceptualised as a trigger between no demand and demand for a service.

In addition to the demand surges, demand was also observed to *steadily increase* until the system capability became overwhelmed. Although demand increases were expected as an integral part of the systems goals for organisations, the threat appraisal of being overwhelmed is often not perceived. As discussed in D15:

> First couple of weeks were quiet because it was the beginning of the campaign [to attract new customers], but as more people started seeing it, more ads, the sales team started getting into branches, getting onto bigger clients and focusing their processes as well so they were more effective, the applications increased.

A few systems based their decision-making (and wider business model) on demand rates having peaks and troughs. In other cases, the levels of demand did not increase, however it remained constant when it was anticipated to decrease. Therefore, a disruption manifests itself when demand rates remain higher than anticipated, as identified for one scenario discussed by D7

> Usually you would have a rush from about 6(am) to 9(am), then it [customer demand] would be dead[15] until about 11(am), then dead again at 1(pm). But that morning it was just like 6(am) to 11(am).

Although the system may possess robustness to cope with high levels of demand, it is expected that these levels may drop. This was discussed within D6 whereby a future disruption in the form of a product stock-out was anticipated as the actual demand differed from perceived demand.. Therefore, the two previous demand patterns—steady increase and constant—can be argued as overwhelming the systems robustness, and the system was able to cope with the increasing levels of demand up until a point.

Finally, on occasion demand had the inverse effect to the previous three patterns, whereby demand either suddenly or progressively dwindled, impacting the system's ability to achieve its goals. For example, D6 discussed a disparity between customers perceived as attending prior to the event, and actual customers who attended, requiring a reactive response to sell-off surplus stock:

[15] i.e. period of low demand relative to other times of the day.

> I thought that it was going to be poorer, but I didn't think it was going to be anywhere near as poor. I expected about 80. So I ordered about 90 kits, so then I got 40 people.
>
> It's not even about the wastage in our business it's about the cash flow. Wastage, there's normally pretty low wastage because you can always push the product back to warehouse, you can push the product to another store, you can put a sale on just to make the COGS (cost of goods sold) back. The problem is, storing thousands of dollars in a product that then doesn't move, that could be anything else. And you ended up as someone who is in the industry, you sit there and you micro-manage your stock like nothing else.

Another perspective on slowdown demand was discussed in

D19, where external renovations lead to a severe shortage of customers for a small store, similarly leading to attempt to stimulate demand:

> We were at the end of a corridor...no one knew we were open. We used to have, one of the security guards would be open that corner, and people would try to walk down and he's like 'nah there's nothing done there'. Like, we are!

4.4.2 Supply Disruptions

As discussed within Chapter 2, the idea of a supply-side disruption can be generalised towards any system as an upstream disruption (however for the purposes of clarity the thesis will continue to use the phrase ‘supply’ to reflect the upstream importations within a system)..

The shortages of supply discussed in the interviews were often a consequence of surges in demand, however these also occurred as standalone disruptions. The magnitude of these disruptions was temporal; for example, when broadly discussing the impact of subcontractors not showing up to a worksite, D23 appraise these disruptions as being minor in magnitude for the most part, noting that:

> It depends on [the] job-to-job. So if there's a bigger job, [subcontractors not turning up] doesn't really matter. [On one particular job site] we were there for 8 months straight, so you push something back by a day it's not really going to matter. But when you've got 6 to 8 smaller jobs booked into a week, then if you don't complete that job on the day, it pushes everyone back a day. Then you have to make that day up somewhere else, so you have to get either employ someone else on another job, or pull someone off one of your other jobs that aren't time critical.

Another example of acting to prevent future supply issues was discussed in D11:

> The supplier's required under the contract to have a risk management plan, a risk management strategy in place. There [is] monthly submissions of the delivery of program, which they have to status against. And then there's typically weekly, informal reviews of their status against their delivery program. All of those identified the fact that there was highly likely to be a delay, which was acknowledged by everybody but the supplier.

4.4.3 Forced Adaptation

Another type of disruption discussed within various interviews involved forced adaption, whereby there is a degree of system restructuring in which the individual loses the agency to act *against* the particular change. Within these disruptions that system faces an adaptation either due to either endogenous or exogenous forces. Accordingly, the individual needed to adapt in order to ensure their viability within the system. If the individual did not undertake flexibility to adapt towards new system organisation the results were not ideal, as noted in D21:

> [If the individuals did not adapt towards new system requirements]. We'd be up shit creek[16]. Theoretically, the manager...if all of us refused, I mean, we'd probably, most of us would get fired.

[16] Slang phrase referring to an 'awkward situation or unpleasant predicament'. https://www.phrases.org.uk/meanings/up-shit-creek-without-a-paddle.html

The causes that lead to components being restructured varied across interviews, however the implications were similar; that particularly steps needed be taken to ensure either agent or focal system viability. The event D9 looked at how the system (i.e. the private university and thus the employee) needed to restructure particular components in order to ensure that the business was in line with new government legislation:

> In that period (October to December) we had to upgrade all of our vocational courses to a higher education, university qualification…we had like 3 months to take about 50% of our courses, completely re-do all of their subject outlines, course structures, course codes, not to mention all the administrative things behind that, and move, you know, several hundred students across from their existing courses into that [new structure]

Another type of forced adaptation was caused by a takeover, whereby extant business practises needed to be adapted towards the new organisational procedures (D18):

> I think the big company that bought us [store] out didn't want to make too many changes, so I think it took about another 3 months [after the takeover] for things to start changing, like just little things like how you did your banking, or all the paperwork at the end of the day, how you deal with all that.

In addition, D21 discussed the impact that a segmentation from their organisation's parent company had on operational procedures:

> A couple of weeks ago, a month probably now. We've got to go through several processes to close up now, from, we've had to get our own safe installed. We've had to change a couple of our products, we were simply selling [previous parent company] products at the time because we could. We can no longer [sell their products exclusively], they updated our register system, our computer system is changed.

For the systems that discussed restructuring, it can be suggested that numerous social systems are vulnerable towards this form of evolution and emergence proposed by Anderson (1999). Although the interviewees of these disruptions discussed how it impacted their day-to-day roles (in other words, not how the peripheral suprasystem behaved), they still offer insight into how focal system components react to such events.

4.4.4 Goal and Job Alignment

Borrowing the idea of a system performing 'jobs' as described by Christensen et al. (2007), the idea of goal-based disruptions emerged primarily out of interviews whereby the disruptions did not adequately fall into either of the three previously discussed categories. These types of disruptions can also display demand and supply based characteristics discussed in the previous three categories, however there are several scenarios whereby the disruption was more accurately described as to an inability to reach a defined goal. As discussed in D24

> They [client] just expected that 'you guys move freight all the time, so you can move seventeen [large products] in two weeks'. It's not the same, so it worked out in the end, but I think we only got away with it because they also, not looked stupid, but I think they realised just the enormity of what they were actually asking.

Although the above disruption was ultimately rectified, it highlights the emergence of a disruption from a goal-based perspective; namely, the inability to find an appropriate supplier to move their client's products. Similarly, D27 speculated about the impact of not being able to adequately prepare particular meals within a restaurant:

> Scenario could have been customers coming back from having it [food] the previous week, could have come back and had a less quality, then they could have resulted on bad reviews.

As complex systems often possess multi-goal seeking behaviour, it is not surprising that a system will not always be able to satisfactorily meet these goals. This suggests that systems may not operate on a strict survive-or-fail binary. Instead a disruption temporarily shifts a system into a state of chaos whereby its ability to achieve goals (and thus maintain stability) may be uncertain. As discussed in Chapter 2, open systems are always susceptible towards competing forces of order and chaos, thus a disruption can be reconceptualised as a chaotic force (this is discussed in greater detail in the

following chapter). With this context in mind, the individual action undertaken serves as a mechanism to return the system towards its regular order equilibrium.

4.5 Threat and Coping Appraisals

The threat and coping appraisals were important influencers on the action undertaken. The appraisals were varied across several characteristics relevant to the interaction between the disruption and the system. Namely, the emergence of a disruption (e.g. whether it was detected or unexpected) influenced the temporal scope and the ability of an individual to appraise both the disruption and their ability to act.

Furthermore, individual appraisals were shaped by information and perspectives (i.e. framing) of an individual within their systems, and thus may have differed from both other actors in the system and the wider supra-system. In other words, individuals were only able to shape their appraisals of a disruption based upon both the information they received and their role within a system.

Four key areas that influenced the threat and coping appraisals were identified. There were directly related towards several interactions between the individual and the disruption, namely whether the disruption was detected,

whether it emerged from routine practises (i.e. everyday roles), whether the disruption was unexpected and the disruption magnitude.

4.5.1 Disruption Detection

As discussed in Chapter 2 the detection of disruptions is often regarded as an important aspect of risk management. The existence of detection mechanisms was varied within the interviews. Often, threat appraisals that utilised detection as an information input were linked to formal risk management protocols established within a system, which demonstrates that the individual was able to see detected risks and act accordingly by the nature of their position within the organisation (as a manager). As discussed in D11

> We identify through our [organisation's] risk forum various risks related to the supplier, and then we put activities in place. So one of the risks is delay to the design program because of their [contracted supplier's] lack of understanding of delivering into [location].

Similarly, for systems that dealt with disruptions as a common occurrence, detection mechanisms often existed as an inherent component of the system. This was evident in the discussion on dealing with clients within behavioural disabilities (D22)::

> The way that you know these things are likely to happen is just because, it's either that they've come into the service and they've been assessed before they came in by an OT, occupational therapist. And they're (OT) like well, we should probably have medication, these are signs of them escalating, things like that. So, when they (client) come into our service, that's ready to go.

Although detection would often lead to an appraisal before an event's occurrence, the temporal scope influenced the utility of various choices. Firstly, the timeframe required to undertake a particular action may not be warranted for a subset of threats as demonstrated within D9:

> By the time you train them up [new workers to assist mitigate the disruption] it was already too late. So you had to use what you already had.

Furthermore, the positioning of the individual within their system impacted the ability to translate appraisals into action. The decision-maker is only able to rectify parts of the system within their direct control and periphery (i.e. within their respective system), and accordingly may not be able to act until they receive a signal allowing such action to be undertaken, which was evident in large, hierarchical organisations. These scenarios may take place despite the detection of a threat as protective action is viewed as burdensome on a system, as discussed in D9 when discussing implementing plans to address potential changes in future government legislation impacting private universities:

> There was no certainty that it [new government legislation] was going to occur, at least at the level that I worked at, so to completely overhaul it is a completely huge tremendous undertaking, and it didn't happen until it was definitely passed through.

In such cases, it becomes difficult to implement any protective choice when a disruption is not guaranteed to occur. The factors that influence this are varied; within the context of system discussed above the lack of action was driven by other actors in the organisation. As most organisations would have hierarchical structures, it would not be uncommon for individuals to not be privy towards all decision-making that happens within the wider suprasystem. Consequently, if a disruption does occur actions that lead towards mitigation may not be appropriate until an individual—or subsystem (e.g. a business unit)—receives authorisation. Therefore, the role of power within a system influences the ability of an individual to act with agency, supporting the literature on agency discussed in Chapter 2.

Another perspective on detected threats is that for systems that deal with disruptions as a core goal, the probability of an event occurring may not be subject to a temporal timeframe (where the disruption is going to occur at a known point of time). D22 elaborates on this point when discussing clients with behavioural management problems:

> There's people that [there is] in their [behaviour management] plan that they do it [disruptive behaviours], but they might only do it every 6 months.

Thus, it becomes apparent from these various interviews that there is no clear determinant that a detected threat necessitates action. In other words, there are more complex factors at play than just assuming if a threat is detected an individual will automatically act towards it. This leads to the suggestion that other system factors—whether related to individual agents or other components—play a role in influencing both the utility of available choices and ultimately the decision to undertake a course of action. This support the ideas of a triadic relationship between the individual, disruption and system (Scheibe & Blackhurst 2017).

4.5.2 Routine Practises and Appraisals

A common disruption emerged from routine practises, predominantly in the form of unanticipated demand. Describing a planned marketing event to attract more customers to sign onto a product offered by a major bank, D15 outlines:

> They'll [marketing department of organisation] lower the pricing and streamline the application process to try to make it [application for new customers] for more user-friendly, get more clients, get more trading happening which means more brokerage, more revenue. And so they reduced the brokerage through that, they put lots of media out through the website, sent newsletters out, and as a result of that there was an influx of applications, which was larger than expected, and as a result the systems we had designed to cope with it [rapid increase in customers] weren't coping enough.

The above description encompasses both the steady increase pattern of demand discussed earlier, in addition to its emergence from routine practises. Accordingly, routine events become a disruption when the number of customers exceeded the initial perception. Hence, there appeared to be a lack of proactive appraisal of strategies if demand is greater than expected, as the disruption was manifested within routine behaviours of the system.

There was often a point where this routine behaviour became a disruption when the system was unable to deal with changes in demand behaviour. This was outlined in D4:

> I didn't expected as many players as I got [for a particular event], and I had another event on at the time, and it was taking up—I want to say—half the store, and I had the other half for pre-release [the aforementioned event], and at one point, I literally had maxed capacity in regards to our seating.

The impact of unanticipated disruptions emerging from routine practises is that the system may not have had adequate time to enhance existing capabilities. As outlined in D8:

> Usually we'd…know what's going on, someone always tells us and…we have extra staff and extra stock…On the weekend you'll have more staff because you'll know you're going to be busier.

Disruptions that emerge out of routine events consumed existing capabilities in such a manner that robustness is overwhelmed, and the system begins displaying nonoptimal behaviour. Routine events are centred around perceptions of a system's capacity these can be linked to the robustness of a system. This is due to routine practises possessing a degree of expectation concerning the use of extant capabilities and capacities, thus leading to an established degree of robustness and resilience.

Routine events will create an expectation amongst individuals concerning how the system will operate (e.g. the number of customers served). For a variety of potential reasons—outlined in section 4.4.2—the system capabilities to operate in accordance with its expected equilibrium becomes

challenged. Consequently, as the capabilities and capacities begin to be consumed as a higher rate than was expected, robustness is overwhelmed and the routine event manifests itself into a disruption.

4.5.3 Unexpected Disruptions

The interviews indicated a different appraisal processes for disruptions that emerge from non-routine events. A common factor across these events was their sudden speed of onset, often leading to the first available choice being undertaken as a matter of urgency (and subsequently not necessarily being accurately appraised). When discussed their family member who became ill and subsequently required expeditated surgery, D1 outlines:

> He [family member] had some tests that determined that he had blockages in his heart, so obviously he needed to have surgery for that. But at the time when he had it done, it was like 'Well, we could wait and get it done electively'; it wasn't a problem. But on the weekend, he ended up having a heart attack—ended up in hospital—so things happened a lot quicker than they should have.

Continuing with the example of D1, the sudden heart attack resulted in an expedited process for surgery. The resultant expediting of actions was perceived to lead to unintended side effects:

> But then his recovery from his surgery was really quite poor. So he sort of deteriorated very, very quickly and a lot of the issues that weren't picked up from the hospital were the fact that he was still really unwell and had a delirium, and no one seemed to think that was the problem.

This sudden occurrence—which led to reactive actions with unintended side effects—displays a curious interplay between the two appraisal processes and systemic circumstance. Due to the individual's positioning as a family member—and not a medical practitioner directly involved with the patient—the choice was made to outsource the decision-making rationale towards "the experts" (quoted from interviewee). Furthermore, the threat appraisal process was solely focused on magnitude and was reacting to an unexpected event.

Within these types of scenarios—whereby the enacting of choice is outsourced—the individual can be expressed as losing the power to make choices, linking back to the discussion of agency in Chapter 2. The loss of agency in this instance is not necessarily suboptimal as the individual was not able to enact any protective choices themselves. However, it does suggest that system circumstances can result in outsourcing being the most optimal choice.

Similar interplays were discussed within other unexpected, sudden events. The scenario described in D16 with the Australian Stock Exchange (ASX) unexpectedly crashing rendered the interviewee's clients unable to place orders within the online system and limited their [interviewee's] agency:

> There's nothing [that we can do]. There's no market, the market's gone so we can't do anything about it.

The loss of agency occurs due to the root cause of the issue—an IT system crash—being outside the individual's scope of influence as a broker. Similar sentiments towards unexpected events were outlined in D10 regarding an IT failure:

> This was a freak accident. It was an error in the IT side of it that wasn't caught and went on for a significant period and time, and it wasn't until after all the damage had been done that they realised, and it was too late [to rectify the issue].

A further point about unexpected disruption was outlined in the discussion around a co-worker being injured within a two-person job operation (D5):

> He [employee] was going to come back in again and then work a half a day and then I'll work a half day because it was just us two and then our new employee I had hired, because of some employee changes. Now he's *down for the count*[17], I had to be in the store for over 24 hours because I got my [new] employee in, but she did not know how to run these events. So I had to stay for the whole thing. So, I was in store, working essentially for over 24 hours. And that as obviously…that's terrible, for a lot of reasons.

The above quotes surrounding unexpected disruptions can be linked to two areas of the literature discussed in Chapter 2. As these events were unexpected and sudden (and thus may have fallen outside the individual's appraisal of likely events), they can be regarded as constitutingBlack Swan events (Taleb 2007).

Second, bounded rationality will render an individual unable to imagine all possible disruptions that may occur, and accordingly system detection mechanisms may be restricted to extant, known disruptions. Although for unexpected events the appraisals are shifted towards a reactive response, this does not suggest that reactive responses are the suboptimal choice. This idea is discussed later in section 4.6.1.

[17] i.e. unable to work because of an injury. Emphasis added by author

4.5.4 Magnitude and Coping Appraisal

Another interplay was between the coping appraisal and the magnitude of a disruptionD10 outlined this point when referring to the sheer size of the magnitude caused by the IT glitch corrupting student personnel files:

> It's so much stuff [the number of files lost], and you might not be able to recover the grade, but you can recover part of the assessment, things like that; it was a real, you know, huge mess.

With D13, addressing a disruption in terms of a surge in demand can only be implemented to a certain magnitude:

> The best-case scenario was just trying to get as much stock on hand as possible [to mitigate demand surges], and obviously once the supplier ran out, that was basically the end of the story.

Furthermore, appraisals of individual abilities—across a wide variety of possible actions—influenced the utility to mitigate a wide magnitude, as discussed in D28:

> It takes a lot for me to accept defeat in fixing things like that, especially in food because I've learnt so many techniques and tricks that there's nothing really that I can't do, it just takes even longer or it's a lot more stressful.

As demonstrated in D15 an appraisal of an event's magnitude determines the utility of a certain choice:

> If it's [a particular disruption] really, really bad, then yes we'll bring in other people but that's usually [a] last resort because those people have their own jobs they need doing, and if they're not doing it they're falling behind in whatever they're doing, so that's last resort.

For disruptions with low perceived magnitudes, other factors influence the efficacy of choice than solely just to mitigate the disruption. For example, D23 discusses the risk of sub-contractors not turning up for work within the plumbing industry:

> You've got to presume they're [subcontractors] going to show up. If you're going to say 'they're not going to show up', you're going to get 5 subbies [subcontractors] and hope that 3 of them show up. Then if all 5 of them show up you've got to pay them for a full day and you're going to lose two grand and it's like 'well what was the point of that'.

This suggests that an important appraisal—as part of the efficacy determination—is the viability of enacting a choice. Although the ideas of self-efficacy Bandura (1977) and the original models of PMT are focused on individual ability, future iterations of PMT (Lindell & Perry 2012), acknowledging the influence of impediments e.g. time and resources) in the ability to undertake a choice.

The interviews as a whole support similar findings by Bubeck et al. (2012); Grothmann and Reusswig (2006) that threat appraisals (i.e. probability

and magnitude) are not the sole determinant of undertaking choice. Although the threat appraisals did play an important role in influencing whether to undertake action, both disruption and system circumstances played a dynamic role in influencing the individual perceptions of agency (and thus efficacy).

4.6 Choice Types

The protective choices undertaken by individuals took the form of several types is reflective of both the conceptual framework and emergent themes. The conceptual framework argued that a choice can be broadly classified across its temporal scope (proactive, reactive) and strategy (redundancy, flexibility).

Although these themes were common across the interviews, several emergent themes offer insights into different choice types. Namely, the rapidity of an action—influenced by the 'fast' intuition' and 'slow' reasoning discussed in Chapter 3—lead to a degree of demarcation whereby choices could be expressed as following either a structure or unstructured approach[18]

4.6.1 Temporal Scope

As discussed in Chapter 2, choices can be delineated by their temporal scope, namely proactive (i.e. before a disruption has occurred) or reactive (i.e. after the disruption has occurred). The results supported the demarcation of choice, in

[18] Although Table 5.2 discusses 'unstructured versus structured' as an emergent code, the phrases 'intuition' and 'reasoning' will be used to ensure that these ideas are both linked to extant literature and also the continuity of phrase in the thesis.

particular the idea proposed by Zhao et al. (2019) whereby proactive choices can also reflect scenarios when a disruption has occurred but the impact has not reached the focal system.

Proactive Choices: Adopting the traditional pre-disruption perspective on proactive choices, these choices required a mechanism that detected a disruption prior to its occurrence. Therefore, these choices were restricted to systems that possessed such mechanisms, although the detection of a threat did not guarantee an action would be undertaken, as discussed in section 4.51.

For disruptions that emerged out of routine events, there was often a degree of proactive planning involved, as outlined by D4:

> [Prior to an event] We get an allocation of stock, including a certain amount excess on top of what we've done previously on average, and I have to 'guesstimate'[19], essentially, the number of participants I'm going to have [arriving at an event].

Within scenarios like the above quote, the individual proactively enacts a choice to deal with anticipated surges in demand. However, the disruption emerges as the robustness of the system is consumed at a rate greater than what the individual had perceived.

[19] Portmanteau of guess and estimate

Proactive actions required a degree of disruption detection—, such as a contractual obligation on suppliers to have risk management systems in place (D6)—although discussed earlier in section 4.5.1, detection did not necessitate action; such as D7 whereby the interview discussed their boss being unwilling to appreciate the seriousness of a detected disruption. Therefore, for proactive action to be undertaken there needs to be a combination of both disruption detection and the ability for an individual to proactively act.

Reactive Actions: Within the interviews the most common temporal scope was reactive strategies as in the table within section 4.3. This may be attributed to several reasons, such athe differences in how individuals were able to detect disruptions, as both the lack of detection mechanisms and the individual's positioning were determinants in these factors. Therefore, the context of the interviews could explain the dominance of reactive choices.

Reactive actions were common across goal-based disruptions. There were scenarios were the system was overwhelmed due to the unexpected emergence of additional work (e.g. such as the last minute request for a substantial volumes of property valuations reflected in D29), unexpected surges in demand and issues that impeded the achievement of goals within routine practises, such as the inability to find an appropriate logistics provider for particular products in D25 and D26:

For mortgage-based work there's a 2 day turnaround, inspection report delivered. But for government based stuff because it's so big and so different kind of report, it's longer, usually it's like a month, But for some reason they left it last minute, so they grabbed us because we said we'll do it and no other firm would do it. Because it's such a small-time frame. So we did, and obviously it was just so disorganised and hectic and yep, tenants weren't being home. [D29],

Every single shipping company we approached didn't even review what we wanted the just read it; read the email we sent them and replied 'no'. One guy just said 'you guys are idiots'. [D25]

> At first I've never seen anyone ship it, and that was where got stuck because I've just said "I'll send a booking to the US, here you go blah blah blah". And I said to him "I've never shipped this before, could be a problem but we can usually do anything". And that's how I got into all the shipments "yeah yeah we can probably do that don't worry about it". But this particular customer, he takes that sort of speak as guaranteed 'you said you could do it' sort of thing. I sent it to the US and obviously they're one day behind us, so I don't see the reply till the next day, and that was on a Friday. So by the time I get in on Monday, I see that they said 'this is hazardous goods, you can't ship it with these shipping line and this shipping line, and it's illegal to be airfreighted anyway'. [D26]

Similar across other demand based, namely constant demand and steady increase demand, individuals did not act until the disruption had begun to negatively impact system performance. Therefore, within these scenarios the unexpected event immediately overwhelmed the existing system robustness.

Although reactive choices were often linked to unexpected events, reactive actions themselves were not suboptimal choices. D28 highlights this point, as prior learning and experience as a head-chef influenced their ability to reactively act:

> So that [previous experiences that required adaptability] taught me so much about adaptability skills and now I'm pretty much able to adapt to any issue and problem and stuff like that.

Therefore, reactive events were the ideal choice for systems where adaptability was a key component, as both the above quote in D28 and the two systems (D2/D3 and D22 respectively) that dealt with volatile client behaviour as a core component. Within these scenarios the action against a particular disruption is reactive, however the training that enables individuals to be adapt to a wide range of scenarios is proactive.

The results support the existing literature that argues for a demarcation between proactive and reactive choices as discussed in Chapter 2. A key differentially is that the results demonstrate that there is a holistic relationship between the individual framing, the disruption type and the temporal scope of the choice. Therefore, these need to be considered as interconnected rather than independent factors.

4.6.2 Redundancy/Flexibility

As discussed in Chapter 2, redundancy and flexibility are two broad types of choices that aim to prevent and/or mitigate the impact of disruptions. As the discussion within the literature often centres around the utility of these strategies (e.g. Sheffi 2005a), the results offer an interesting insight into the deployment of these choices.

Redundancies were found to often be utilised in scenarios where a disruption occurs suddenly or was unexpected. At times there were more than one type of redundancy available to the individual, as discussed in INT3:

> I decided not to make a decision, or in a lot of ways my decision was I'll put myself on, and I'll deal with the lack of sleep, even if it negatively impacts the events, I thought it was a better negative impact than doing the other options.

In the context of this interview, the 'other options' included further redundancies (such as bringing in staff from outside stores). However as this was not perceived to be an ideal choice, it may suggest differences within the utility function of different redundancy strategies.

When describing redundancies, a common theme highlighted within the interviews was the idea of unexpected consequences that arose from (often reactive) redundancies. D15 highlights this point:

> The first response [to increased demand] was just 'chuck[20] more people onto processing [application forms]', to try and stem the flow. But even that didn't help as much because that was a short [term] fix, so it's alright to say 'we'll get an extra 10 people to work on the applications', but why is this person [client] getting this tax form…wrong 5 times before he actually gets it right?

Although this was used as a choice to meet the increased levels of demand, unanticipated outcomes lead to a reappraisal of the appropriate course of action. Namely, as clients were having to complete an application form multiple times, this increased the overall workload for the system, which eventually lead to a reappraisal of the disruption in terms of the appropriate strategy (D15):

> The issue was you had applications, say from last Wednesday, that we sent to them to check, and they've just got back to us on the [following] Monday, plus all the one's that's [INAUDIBLE] on the application, so that's how it [demand] builds up.

Another example of the unintended consequences arising from a reactive redundancy was discussed in D7:

[20] i.e. increase the levels of.

> So, because the milk that was generally use is 'light', and designed for steaming, you can't get that at [supermarket chain], so we had to go and get full cream milk and skim milk so we could satisfy all of our customers, which added extra strain to us because the operation itself works so well because there's only one type of milk.

Another issue with enacting redundancies was the temporal lag in these strategies. This involved cases whereby enacting a redundancy would involve a time intensive process that is not reasonable within the described scenario, as reflected in D22:

> If you want to get [get] more staff, you have to re-do their [client's disability support plan] and get new funding for it. So, the way that they're [organisation] sort of getting around it, with my company at the moment, is we made the crisis team, which I'm in. It's got more staff that…[have] more experience dealing with clients with higher behaviour.

A similar sentiment was found within D13: when discussing the idea of importing a sold-out product from overseas:

> We could have bought it [sold out product] overseas but we [organisation] would have been in deficit. It wouldn't have worked out as a profit, it wouldn't have been worth it.

However, for several systems 'doing more of the same' was a by-product of the individual's job. For example, within D25 and D26 the individual's response to

an inability to find an appropriate logistics provider for their client was to continue searching for additional suppliers. As this is linked directly to the individual's job, it challenges the idea of redundancies being a waste (as espoused by some in the literature such as Sheffi 2005a), as within these contexts a redundancy is not a physical entity.

Flexibility: The results broadly support the idea of flexibility being multidimensional (Stevenson & Spring 2007) as they took a number of forms depending on the disruption and system characteristics. For systems that inherently dealt with disruptions (namely disruptive behaviours), training often increased the utility of flexibility strategies as it provided frameworks for adaptability, highlighted within the following quote from D22:

> The way I'd say it, it's [training resources] kind of more just a framework to work off, as a diagnosis, because it doesn't really tell you what they're [client behaviours] like, it's just sort of a starting point rather than nothing having any clue. Teaching about it's like a framework, but how to actually do it is from experience.

Prior experience and training within other systems also increased the utility of flexible strategies, as outlined in D11 when evaluating two different approaches towards dealing with a supplier's failure to meet performance targets:

> One's more stepping back, standoffish, legal, commercial, writing letters that sort of thing. Versus the approach that we did take which was to step in closer to them, work more closely with them to try to rectify the various issues they were having.

For disruptions that arose out of system restructuring, the individuals interviewed were often required to undertake flexibility initiatives in order to remain viable within these new system parameters, as noted in the following example by D9:

> Because we had to [overhaul existing courses within a private education provider], because the courses we were [currently] offering wouldn't 100% be funded by the new government loans for vocational courses.

Within system restructuring there were two interesting perspectives that delineated flexibility into several dimensions. The above quote demonstrates a disruption whereby the individual needed to adapt existing courses; this can be conceptualised as flexibility in the product offering.

Conversely, there were a few scenarios whereby individuals were required to learn new skills in order to remain viable within the system, as demonstrated in the quote below:

> So we had to learn new systems for that [new organisational structure]. But then, POS [point of sale] didn't change until a couple of months after that, and then you'll find out "This person is now in charge of doing [a new managerial task]","you gotta [sic] send emails to this marketing person, this is your new marketing person'. Or how they did signage and everything like, we used to get people to come in to do it, whereas they just send it through, they changed it and sent is through email, you print it and they put it in the windows that sort of thing. [D18]

Although this can be also be presented as another form of flexibility in the product offering (with the individual's service as the 'product'), it is argued that this differs from the flexibility discussed in D9 because the agent is the system component that is undergoing forced adaptation, where adaptation is inevitable As forced adaption often shifts the focus of viability from the system to the individual (primarily through maintaining employment), it becomes apparent from the various data points that flexibility, expressed through learning new tasks, is the only viable choice.

However, this method of flexibility—whereby it is the only choice available to individuals—reflects a unique subclass of flexibility. Within these cases, the 'necessitated flexibility' is the product of a certain disruption; namely that the individual needs to adapt or they perish as agents within the system.

Other scenarios involved disruptions where flexibility was the preferred option over redundancy, as noted in D23:

> That's the good thing about having agencies and subcontractors; you can say 'see you later' for a week, so you just have to program your months out and know what's happening a month in advance, so you can say 'I'm going to be busy in a month, let's get this thing knocked over while we can, and let's get a couple of subbies[21] in to finish it', and then lead in to the other work. So, it's all about managing your workforce and getting the right number of guys on site. So if you have too many guys on site early, you're gonna [sic] have no work for a week, and then your full-time employees you still gotta [sic] pay them, and you gotta [sic] find work for them and you've got no work for them, those five subbies you paid is useless.

Within some scenarios, flexibilities emerged when previously enacted redundancies did not have the desired outcome, as is demonstrated in the case of D15 where the initial reactive redundancy strategy did not lead to optimal outcomes:

[21] subcontractors

> But that was the first sort of step and then from there, we went into 'why are these clients getting these forms wrong. Are there certain parts of the form that they're getting wrong?" So we started recording were they [the client] inputting their name wrong, or the dates wrong. Because US form you have to do it in month, then day, then year. So we started collecting all that data and after a couple of weeks we sat down and looked at the thing and went "Alright, we can see that these are the common points in the form".

Throughout the interviews the emergence of redundancy and flexibility as choice types was quite different to the extant literature discussion in Chapter 2. Firstly, the strategies were often not clearly defined as being one of these two choices, therefore the contextualisation of choice (as part of the wider system framing) becomes important. Namely, whether a choice strictly falls into a redundancy or a flexibility became almost a moot point; rather individuals will undergo the path they deemed do likely to mitigate the impact of the disruption.

Furthermore, rather than compare the two strategies are separate choice types, individuals were more likely to explore a variety of options based on the nature of the disruption. This in turn resulted in people often following the first choice that came up (i.e. a fast action), or an evaluation of various choices (i.e. a slow action).

4.6.3 Rapidity

As individuals would often follow the first choice that came up, their individual actions could be expressed according to its rapidity. Based upon the ideas of intuitive versus reasoning choices discussed in Chapter 2 (section 2.8.2), choices could be defined as being either 'fast '(i.e. instantly enacted) or 'slow' (i.e. lag between choice to undertake an action and explicitly undertaking the action). Initially these codes were based on the classification of choices as aided-analytic or nonaided-analytic as discussed in Beach and Mitchell (1978), however a number of interviews utilised choice procedures that did not fit directly into the strict categorises offered by these codes. Therefore, a broader classification of the timeframe that the choice was enacted is applied.

For 'slower' choices, the utility of the choice undertaken was often derived from a feedback mechanism based on experience. Individuals were able to slowly appraise the utility of choices derived largely from extant experience, as discussed in D11:

> On previous contracts, the formal commercial mechanism [one of the strategies available to mitigate disruptions] has been demonstrated to not lead to a good outcome for any party. Experience suggests that's not the way to resolve it, especially this early in the project; there's a time and a place for it and that wasn't it.

This was not a surprising finding, as experience is one of the mediating processes that inform choice within PMT (Rogers 1983). In other scenarios, the 'slow thinking' process was a culmination of discussions with other people to evaluate different strategies. By engaging with other individuals with the system, a wider appraisal process takes place; as shown in D24 when a supplier did not deliver critical items:

> We were just tossing up whether it's quicker-driving from [work-site location] to [supplier location] and back on a Friday afternoon would have been horrendous, so it's like you could spend 3 hours in a car. We were tossing up how we were going to get it there, calling [main client], calling other suppliers of the same material and seeing if they could deliver. And then someone came up with the idea of just getting Uber to drive one way with it, and then we booked an Uber, and they were quite happy to do it.

Within most interviews, fast choices were often reactive, primarily due to the disruption being unexpected. Within several scenarios, the resultant fast actions

lead to suboptimal outcomes. Reflecting on their manager's action, D7 describes a scenario that appears to be indicative of the suboptimality of 'fast' actions:

> He'd [the manager] left for the day. He said before he left, he noted that we were running a bit low [on milk for a cafe], and so he suggested at some point "[Individual]'s going to have to get a bit more milk', but kind of brushed it as a non-issue. When in reality, because of [on] an afternoon there are way less staff on, it was quite a blow.

However, although fast choices are often automatic and based on intuition (as discussed in Chapter 2), they were not necessarily the suboptimal choice. As discussed in D28:

> Yeah so when I saw that, that error, it was instantaneous, it was not 'oh I'm going to play around with this for a little bit'. It was 'no, this was something different, I'm not going to even bother playing around with this oven, because I don't have enough time'. It was instantaneous that I started doing the new actions because I knew that I only had a limited amount of time.

Similarly, the systems that dealt inherently with disruptions–notably D2/D3 and D23—were reliant on fast decision-making, however like INT15 these were the culmination of both training and experience. Within these scenarios, the fast response towards the disruption was the most optimal choice. This differs from the premise that fast thinking is often automatic and thus on occasion effortless

(Evans 2008; Kahneman 2003) as the individuals purposely act in a rapid manner.

4.7 System Response and Outcome

The transient response of the system—triggered when the disruption occurred—was a difficult phenomenon to capture in interviews due to the dynamic nature of disruptions. Namely, the idea of a 'starting point' varied across several interviews, particularly influenced by the disruption behaviour. For example, in scenarios where the disruption arises from demand behaviours, the trigger point of a transient response varies between demand surges and constant-level demand.

Rather than try to capture the 'trigger point' of transient response—and thus a strict time-stamp of when a disruption begins to occur—the following section focuses on several unique system outcome behaviours, expanding further than the survive/failure dichotomy discussed in the conceptual model. These behaviours are described as *responsive return*, *disruption dissipation,* and *system failure.* Whilst the first three indicate outcomes where the system by the individual remains viable, system failure refers to both the 'collapse' of a system, or the inability for it to meet goals and thus remain unviable. These responses are inherently linked to the resilience of a system as discussed in the literature review chapter.

4.7.1 Responsive Return

The common system behaviour displayed within the interviews was that of the responsive return; whereby the interaction between the choice and system lead towards any major consequences being averted. Although the interviewees were not asked to demonstrate a causal relationship between the choice and the responsive return, this was inferred by several cases. For example, D29 stated that without the flexibility they enacted to work-through the particular surge in property valuations: "there's no way we could have got it [completed the surge of property valuations in time].

Although this was not explicitly stated within each occurrence, the inference drawn from the transcripts if that the choice was an important determinant in the system's responsive return. The manner of this return is reflective of the system's resilience (as discussed in Chapter 2), as the more resilient a system is, the faster it can return to an acceptable level of performance.

4.7.2 Disruption Dissipation

This behaviour reflects a system response and outcome where the magnitude of the disruption decreases over-time, apparently independent of decision-maker input. For decision-makers tasked with customer service roles, there was a sentiment that demand "fizzled out" (D10) or "slowed down" (D15). The case of student personnel files becoming corrupted (D10) highlights this point:

> So in terms of what happened behind the scenes I have no idea, but from a face to face it was just when the inquiries, it stopped coming up so often for us. So students who were impacted or actually gave a damn were resolved, or a solution had been offered, that's when it kind of fizzled out for me.

The first sentence of the above quote suggests that the disruption cause (IT failure) would have had a different behavioural profile in other peripheral systems. Namely as the individual's system was related to customer services, the existence of potential actions to mitigate the root cause of the disruption—the IT failure deleting client records—was not known to them.

This continues with the theme of framing discussed amongst the analysis, as an individual is only aware of the behaviour of their system and is not going to see everything that occurs within peripheral systems. Accordingly, it brings forward the idea that the system response profile—such as disruption dissipation—is limited towards the system boundaries, and thus may behave differently within other peripheral systems. A further idea on this is that it reflects the role of the individual as operating within the edge of chaos until the disruption begins to naturally dissipate.

4.7.3 System Component/Goal Failure

Whilst many of the interviews described scenarios that fit into the above three archetypes of system behaviour, several scenarios lead to sub-optimal outcomes, or system failures. In particular, these were manifested as either the

complete failure of a system component (as was the case with the eventual death of the family member described in D1) or the failure to achieve defined goalsD26 describes this type of goal failure in more detail after a key client left the business:

> So we haven't just lost this customer, but anyone he even goes near is not going to use us. His factory that went to ship those goods they're not going to use us to export either, because they're going 'you [expletive] up the last one we'll just use who we normally do'. So we've sort of lost two or three businesses worth of work if we were ever going to get it, they probably won't be with us anymore. So it's more the effort involved; it probably took that sales manager weeks of work to get that business, and then he's going to ship something alternative, we've said 'we should be able to do it' and couldn't, [he just] take everything. In one day, he changed all of it. You know, 800 containers a year's not small. That's a lot, we charge three thousand dollars per shipment, so it's still a lot. The effort to get that, to lose it in three/four months, that's the problem.

Therefore, there is a subclass of system failure that is related back to the goals of the system. This idea is reflective of the multi-goal seeking behaviour of complex systems discussed within Chapter 2 as individuals will have roles within their own systems that are designed to meet defined goals. Therefore, an inability to meet those goals—caused by a disruption—reflects a system failure.

However, as part of a wider suprasystem—such as an individual being part of a business unit that is part of a wider organisation—the localised failure may not have large ramifications for the overall system. The conceptualisation of system failure is based upon the system boundaries, whereby failure in one part of a system may not be viewed as a failure to the suprasystem or other system components. D19 provides an overview of this, as the inability to rectify demand short-falls caused by nearby construction work—which had lead to the closure of other local businesses—did not affect the franchise store:

> Because we were such a well-known big company, and we also have heaps of Melbourne stores as well, and they do really well down there. I guess that's what kept us afloat, and they fact that they (organisation head office) "Oh this [Location] going to be massive when it's finished, we're going to get so many more people in here, [organisation] is just going to boom from there."

4.8 Conclusion

This chapter has presented the results obtained during the interview process. The interview overviews display the interdisciplinary (and contextual) variance amongst the interviews. A discussion of the theoretical implications of the themes emerging from the coding process is discussed in the next chapter, however a few insights are briefly mentioned. Firstly, allowing interviewees to shape the course of the interview was found to be a positive method of eliciting

rich responses, as they were able to reflect on events more comprehensively than try to provide answers to strictly defined questions. This, in turn, allowed for more diverse themes to be uncovered from the interview process and importantly presented the idea of system framing.

The second phase of this chapter outlined the themes in greater detail across four main stages, summarised in Table 4.3. The results offer a unique insight into a variety of individual experiences with disruptive events and serve as the first stage towards system behaviour theorisation discussed in the following chapter. The various emergent themes from the literature are reflective of both the themes presented in the conceptual model and other areas of the literature. The main findings, discussed in the second half of the chapter, are summarised in Table 4.3.

Stage	Major Findings
System Framing	▪ Individual systems interact with both peripheral systems and larger, suprasystems ▪ The systems described by individuals can be described as a focal system engaging with sub-system or suprasystems depending upon the focus of analysis, thus individual experiences do not follow strict system boundaries
System Disruption Profiles and Characteristics	▪ Disruption profiles determined by the system structure and individual framing ▪ Vulnerabilities arose from system components ▪ System goals that require dealing with disruptions as a primary role of the system ▪ Disruption occurrence was captured across several characteristics: 1) Demand behaviours; inclusive of surges in demand, steady increases in demand, demand remaining constant and demand slowdown; 2) Supply issues: contextualised as a lack of inputs rather than consumption caused by demand; 3) Restructuring: shift in (often) suprasystems in the form of takeovers. Also constituted external events that necessitated the system to restructure, and 4) Goal-based disruptions: events that are more closely linked to an inability to achieve goals than the above three characteristics
Threat and Coping Appraisals	▪ Threat appraisals were influenced by threat detection mechanisms, but this did not guarantee action; the ability to undertake action was influenced by 1) Suprasystem influence; 2) Efficacy, and 3) System structure; whereby particular disruptions can only be addressed reactively ▪ Disruptions from routine events were unexpected but from known sources, often linked to demand ▪ Unexpected disruptions often arose from unexpected sources ▪ Coping appraisal (namely efficacy and perceptions of agency) were linked to perceived magnitude ▪ Appraisals of the viability of an action became an important consideration; consisting of both whether an action would have the desired outcome and if it is feasible when compared to other actions

Choice Classification	▪ Choices were temporal and can be expressed across proactive/reactive measures, however there was no definitive link between outcome and temporal scope (i.e. proactive and reactive were shown to be effective strategies in different scenarios 1) Proactive action was often related to perceived magnitude and the existence of threat detection mechanisms 2) Reactive strategies were more common (20 out of 26 disruptions) ▪ Systems that dealt with disruptive behaviours acted reactively but utilised proactive training and experience ▪ Redundancy and flexibilities strategies were more than just a binary between the two; often there were multiple redundancy and/or flexibility strategies available 1) Redundancies often lead to unintended consequences either due to operational issues or a suboptimal outcome 2) Redundancies were further subjected to temporal lags which impacted the perceived utility 3) Reactive flexibilities were common across several systems, linked to training and experience (which thus benefited the individual's coping appraisal) 4) On occasion flexibility was the only choice available for an individual to ensure their viability within the wider suprasystem (often in the case of system restructuring) ▪ The individual choices could be attributed to an either immediate reaction (fast choice) or more considered approach (slow choice): 1) 'Slow' choices were often resultant from procedural or group discussions 2) 'Fast' choices could be both suboptimal (where the consequences of the choice were unknown and thus lead to suboptimality) and optimal; on occasion individuals had sufficient training and experience to react quickly and effectively to events
System Response and Outcome	▪ Transient response was difficult to capture in terms of a time series due to variations within individual appraisals as to when a disruption begins. ▪ Response and outcomes were displayed across several behaviours, namely: 1) Responsive returns, where the system takes a 'hit' from the disruption but returns to acceptable performance measures after enacting a choice 2) Disruption dissipation, where the disruption magnitude reduces over the time. This was common for disruptions that took the form of demand surges. 3) System failure, which incorporated both subcomponent failure and inability to meet goals.

Table 4.4 Summary of Major Findings

As described early in the chapter, data saturation was determined when the interview content was deemed to provide substantial information to analysis both the conceptual framework and the research questions, and when a point of diminishing returns was established. Although this point was subjectively determined, the results offer numerous insights that answer both the research questions and provide the justification for several theoretical ideas discussed in the next chapter.

Chapter 5 Discussion

This chapter provides a discussion of the results from the semi-structured interviews. The first section of this chapter revisits the research questions, expanding upon the results of the literature review by incorporating the results from the interviews into an analysis of the research questions.

As the discussion aims to provide key theoretical frameworks emergent from the results, the next part of the chapter briefly discusses the importance of theory development. As the main models proposed in the latter half of the chapter are typologies, a brief discussion linking typology construction to theory development in provided.

Although the thesis does not seek to provide a singular "theory of disruption decision-making" or similar, it gives several key points of discussion emergent from the abductive research approach; incorporating both the extant literature with the emergent themes from the literature. The first of these key points concerns the disruption types; which are spread across four key areas (demand behaviours, supply issues, system restructuring and goal-based disruptions). These four

dimensions culminate in a disruption profile framework, which seeks to provide a holistic overview of threat analysis.

The next section expands upon the choice types discussed in the previous chapter by providing a model of disruption mitigation choices. This model incorporates three key choice dimensions; temporal (proactive/reactive), strategy (redundancy/flexibility) and rapidity (fast/slow). A key consideration of the model is that it does not suggest one choice type is more optimal than another; the utility of these strategies is derived contextually from the disruption and system characteristics. Following from this, system behavioural types are discussed: responsive return, disruption dissipation and system component/goal failure. These behaviour types complete the triadic intersection of disruption, choice and system characteristics—an idea discussed by Scheibe and Blackhurst (2017) and elaborated on within this chapter. The final section of the chapter provides a metaphysical discussion surrounding the idea of a chaotic edge within the social systems analysed in the thesis and posits several questions for future research consideration.

5.1 Revisiting the Research Questions

The following section answers each of the research questions proposed in Chapter 1, utilising both the literature review and results emergent from the interviews. Broadly speaking, the main points derived from the thesis are:

1. The individual antecedent circumstances related to an interrelationship between appraisals of the disruption intertwined with individual efficacy and their perceived agency within the system.
2. The systemic circumstances similarly influenced the individual appraisals of efficacy and agency.
3. Although the system did not seek out to determine the 'strength' of causality between choices and the system of which the individual operates, within the majority of interviews the choice was viewed as influencing the disruption and overall system behaviour.

Although each of the research questions were designed to be reflective of either the disruption, the system or the individual, the emergence of holistic relationships within the thesis necessitates their consideration as a triadic phenomenon. Accordingly, the answers for the individual research questions are expressed across the entirety of the triadic relationships.

(1) How do disruptions manifest themselves within social systems?

Disruptions can take an arguably infinite amount of forms due to an open system's ability to be penetrated by exogenous forces. Social systems governed by the actions

of human actors are thus susceptible to a vast array of different disruptions as informed by the context of the system they are operating in. The manner of which individuals frame themselves (and are framed by system characteristics such as job roles) within their respective systems influences how they will identify and conceptualise disruptions. The interaction of these two concepts: the context of a system and an individual (e.g. a coffee shop where an individual makes coffee) determines that types of disruptions that an individual may engage with.

(2) What are the main characteristics of disruptions?

Although disruptions manifest themselves contextually, the main characteristics can be defined as being related to supply or demand issues (as is predominately the case within organisations), system restructuring or goal-based disruptions. Some of these characteristics are intertwining, as disruptions that inhibit the achievement of goals may emerge from supply or demand issues. Therefore although all disruptions can be viewed as goal-inhibiting due to systems possessing goal-seeking behaviour, a number of disruptions impact particular routine practises (such as the inability to adequately source a logistics provider discussed in D25 and D26).

(3) What are the antecedent and systemic circumstances that influence an individual's choice to make decisions when facing disruptions?

Antecedent individual factors and system circumstances acted together to influence choice. Furthermore, individual factors included efficacy and perceived agency, which arose from both prior experience/training as well as the system positioning in

relation to its wider suprasystem. Additionally, the influence to undertake a choice was linked to the goals of a system (i.e. for the most part individuals were required to act as part of their role as agents within specific job roles), however points of interest emerged at the type of choice undertaken.

(4) How do systemic factors influence an individual's agency to make decisions?

Individuals possess particular roles within a given system, most notably expressed as a particular job role that influences which parts of the system they will engage with and their respective ability to act (e.g. a frontline customer-facing worker versus a manager have different degrees of agency).. The relationship between a focal system (i.e. that an individual is part of) and other direct and indirect peripheral systems and suprasystems all combine to influence individual agency.

(5) What are the main dimensions of choice types?

The results support the extant literature whereby choices can be classified as temporal (proactive/reactive) and as a redundancy or flexibility. In addition, choices can be classified according to their rapidity, namely either fast (i.e. immediate) or slow (i.e. after analysing different options). The results further demonstrated that choices can be classified across a combination of these dimensions, which is discussed further in section 5.5.1.

(6) What is the interaction between these choices (or lack of choices) and the system in which they operate?

Threat and coping appraisals were intertwined as individuals would base their actions on the combined outcome of these appraisals rather than solely on an individual heuristic. Additionally, for many interviews the action undertaken either helped the system mitigate the disruption or manage the impact until the disruption magnitude dissipated to acceptable levels. As discussed earlier an individual's ability to make a choice is directly related to their framing and position within a system (i.e. their agency) and the viability of undertaking a certain course of action.

(7) How do disruptions manifest themselves within system behaviour?

Disruptions are a form of non-linear behaviour that temporary shift a system away from a stable equilibrium into a state of chaos. As systems always operate on an edge of chaos between order and disorder, disruptions can emerge at any point to shift the system into chaos. Therefore, individual choices often exists as the mechanism to shift a basin back into a stable state.

An overall summary of the main answers to the individual research questions is provided in Table 5.1. The results support to overall exploratory nature of the thesis and serve to inform future research guidance discussed in the following Chapter.

Question	Results
(1) How do disruptions manifest themselves within social systems?	Disruptions can take an arguably infinite amount of forms due to the complexity of open systems.
(2) What are the main characteristics of disruptions?	Although disruptions manifest themselves contextually, the main characteristics can be defined as being related to supply or demand issues (as is predominately the case within organisations, system restructuring or goal-based disruptions.
(3) What are the antecedent and systemic circumstances that influence an individual's choice to make decisions when facing disruptions?	Antecedent individual factors (such as efficacy and perceived agency) and system circumstances acted together to influence choice. System circumstances influenced the individual framing of the system and their relative position.
(4) How do systemic factors influence an individual's agency to make decisions?	The role of an individual within a system, and the positioning of the system will influence their perceived agency and efficacy.
(5) What are the main dimensions of choice types?	Choices can be classified according their temporal scope (proactive/reactive), redundancy/flexibility and rapidity (fast/slow).
(6) What is the interaction between these choices (or lack of choices) and the system in which they operate?	Threat and coping appraisals were intertwined. Actions either helped the system mitigate the disruption or manage the impact until the disruption magnitude dissipated to acceptable levels.
(7) How do disruptions manifest themselves within system behaviour?	Disruptions shift the behaviour of system from order into chaos

Table 5.1 Summary of Research Questions

As discussed throughout the thesis the factors that inform the overarching theme of individuals decision-making within systems facing disruptions can be presented across three key areas; individual, disruption and system (Scheibe & Blackhurst

2017). Accordingly, these three themes inform the main theoretical frameworks discussed within the chapter.

Based on the results, several models are proposed to outline the main discussion points arising within this thesis. As these models serve as theoretical frameworks, guidance is sought from the pertinent literature on theory development. Theoretical frameworks are a useful tool as theory development—although at times a contentious and misinterpreted term (Shapira 2011; Wacker 1998)—is essential towards academic development (Hambrick 2007), with typologies being a popular tool towards theory development (Collier et al. 2012). Several models proposed in the latter half of this chapter can be regarded as typologies, a mode of classifying phenomenon according to a common, overarching characteristics (Bailey 1994). Often regarded as assisting to reduce complexity (Doty & Glick 1994), typologies assist in concept development (Collier et al. 2012) as they categorise phenomena across identified dimensions (Bailey 1994) and within the context of this thesis are used to provide a *systems* perspective towards theory development (Burton-Jones et al. 2015).

5.1.1 On Typology Development

With these points in mind, the models proposed in the next sections reflect typologies; whereby common dimensions were ascertained from the results to

inform an overarching theme. For example, the various disruption types serve as dimensions that allow for a holistic disruption profile to be established.

5.2 System Framing

As discussed within the results, the contextualisation of the system—and the positioning of the individual—played a crucial role in the various factors leading to protective choice being undertaken. Referred to as *system framing*, it becomes apparent that an understanding of the overarching environmental structure of the system is an important determinate for system behaviour. Namely, how a system interacts with its peripheral systems (i.e. subsystems and suprasystems) has implications across the three triadic phenomena (system, individual, disruption).

The implications of this are quite significant as individual framing will dictate the effectiveness of their utility construction. Linking system framing with bounded rationality (Simon 1972), an individual's framing plays a moderating role in linking choice to performance outcome.

In order to visualise this phenomena, Figure 5.1 serves as a model demonstrating the overarching system view with peripheral systems in mind. This conceptual model is not a typology as it does not propose system types, however the thesis recognises the value of future research in exploring the holistic interactions of peripheral systems in greater detail.

Within the figure it is argued that an open system will conduct several interactions with various other systems. In addition to its subsystem components, a system will first intreact with its direct peripheral systems where the two systems have consistent contact, such as the operations unit and logistics unit within an organisation. Secondly there are the indirect peripheral systems which have limited contact with the focal system, but they are both subsystems within the large suprasystem.

The interactions extend towards the overarching suprasystem, that will have both direct and indirect communication with other peripheral suprasystems.. Therefore Figure 5.1 serves as a conceptual framework for analysing the demarcation between various actors within a range of systems. The framework can be viewed as a geneneralisble framework within two academic concepts. First, the conceptual framework serves as a generalisable model of an *ultimate supply chain* discussed by Mentzer et al. (2001), which is the totality of organisations involved in the upstream and downstream flow of products and services. Second, the framework serves as a conceptual visualisation of boundary spanning individuals (Caldwell & O'Reilly 1982; Schotter et al. 2017), who are those tasked within organisation to act across defined business units.

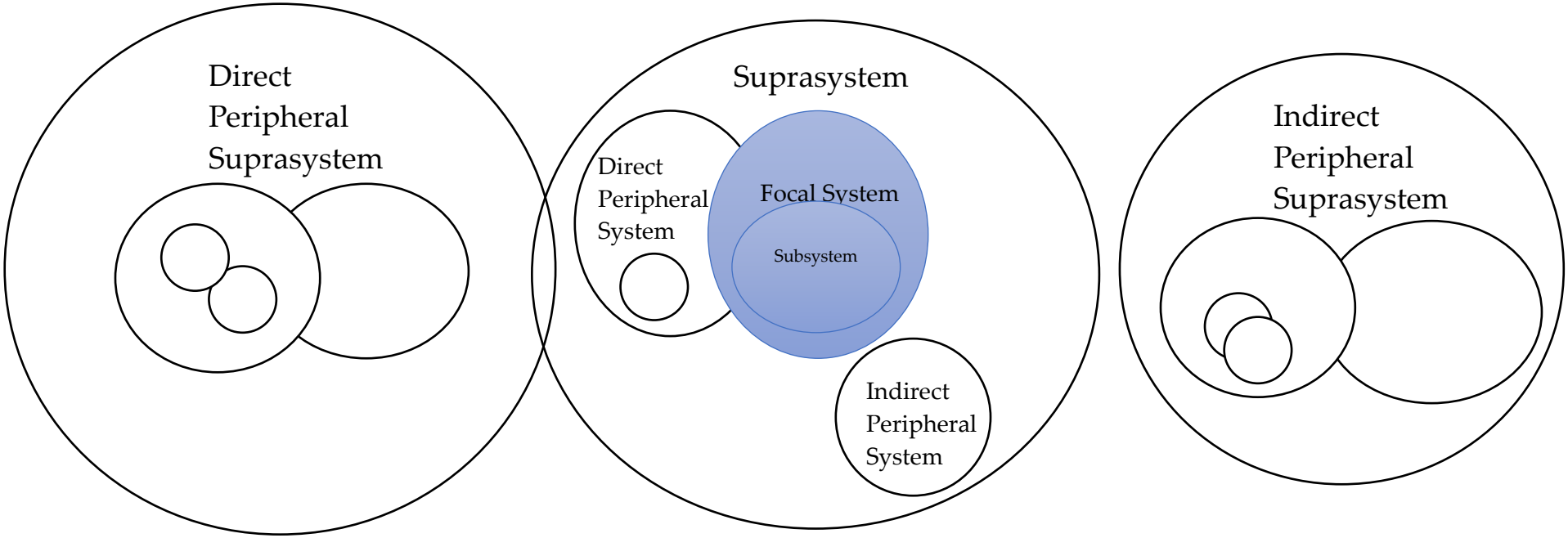

Figure 5.1 Focal System Interactions with Peripheral Systems

5.3 Disruption Types

The results chapter outlined several characteristics that influenced the system disruption profile. Based on this, it is argued that various disruption types exist that emerge from different direct and indirect subsystem interactions. Other disruption types proposed include supply-based disruptions that arise from input issues, reconfiguration caused by (predominately) suprasystem decision-protocols that individuals are not involved in, and goal-based disruptions. The latter type of disruption refers to factors that impact the ability of individuals to reach defined goals; although they may also be captured as demand, supply or reconfiguration-based, these types of disruptions are unique as they are often linked to a specific task.

Disruption Type	**Definition**
Surge	A sudden increase in demand that overwhelms the robustness of a system
Steady Increase	An incremental increase in demand that eventually overwhelms the robustness of a system
Unexpected Constant	A pattern of demand that remains constant despite perceptions that it will decrease at a point in time
Slowdown	A decrease in demand until the system suffers performance degradation as a result

Table 5.2 Disruption Types

It is important to consider that these disruption types are emergent from individual framings. Therefore, they are limited towards extant experiences and thus are not indicative of events that have not been imagined (i.e. Black Swan events). This suggests the possible existence of latent forces not yet uncovered either within the thesis or extant literature.

5.3.1 Demand-Based

Demand-based disruptions—primarily arising from interactions with 'downstream' consumers within a typical business setting—are defined as those that lead to a shift in system performance caused by the characteristics of demand. Like the supply-based disruptions discussed in the following section, these types of disruptions are contextual and most relevant towards business-orientated systems (i.e. organisations).

Demand Surges: Demand surges can be defined as a sudden increase in demand levels that overwhelm the existing robustness of a system. The demand level that overwhelms a system is contextual, as well as its time horizon as it may dissipate over-time or remain constant until rectified. The most common example of demand surges are those triggered by disasters (discussed in Roni et al. 2016), however as demonstrated by the data they can emerge from routine practises within an organisation.

Constant Demand: Constant demand disruptions occurs when an individual perceives that demand will decrease, yet it remains constant. In other words,

whereas the overwhelming of existing robustness for demand surges is resultant from the rapid increase, constant demand instead reflects a misalignment between perceived demand levels, namely an anticipated decrease or dissipation in demand that does not occur. The lack of dissipation highlights the misalignment between perception and reality, as the system is expecting the demand rates to decrease. The most common example of this is a business that expects peaks and troughs throughout a business period and has not appropriately forecasted for demand to remain constant. As the system may design mechanisms (e.g. stock levels, staff ratios) based on demand troughs and peaks, an unexpected constant level can have negative ramifications for system performance. The unique characteristic of this demand profile is that it is unexpected. Choices are most likely restricted to reactive actions when it is recognised that the expected demand downward trajectory is not going to occur.

Steady Increase Demand: In a similar nature to unexpected constant demand, steady increase demand refers to another misalignment between actual and perceived demand levels. In these scenarios, a hypothetical point where the system becomes overwhelmed is reached when demand does not dissipate. This is most likely a result from poor forecasting processes, as the system has only prepared to deal with a defined rate of demand. However, this differs from unexpected constant demand because the system may not have accommodated for expected troughs in demand, but rather suffers from a consistent increase.

Demand Slowdown: The final demand behaviour proposed is that of demand slowdown, whereby demand levels decrease to such an extent that the system (or namely the individual agents) are required to act to avoid losses. Often the losses are cost-related due to both physical product costs and labour costs, which increase the overheads of the system. These types of disruptions serve as opposites towards the three situations described above that outlined demand overwhelming system capabilities.

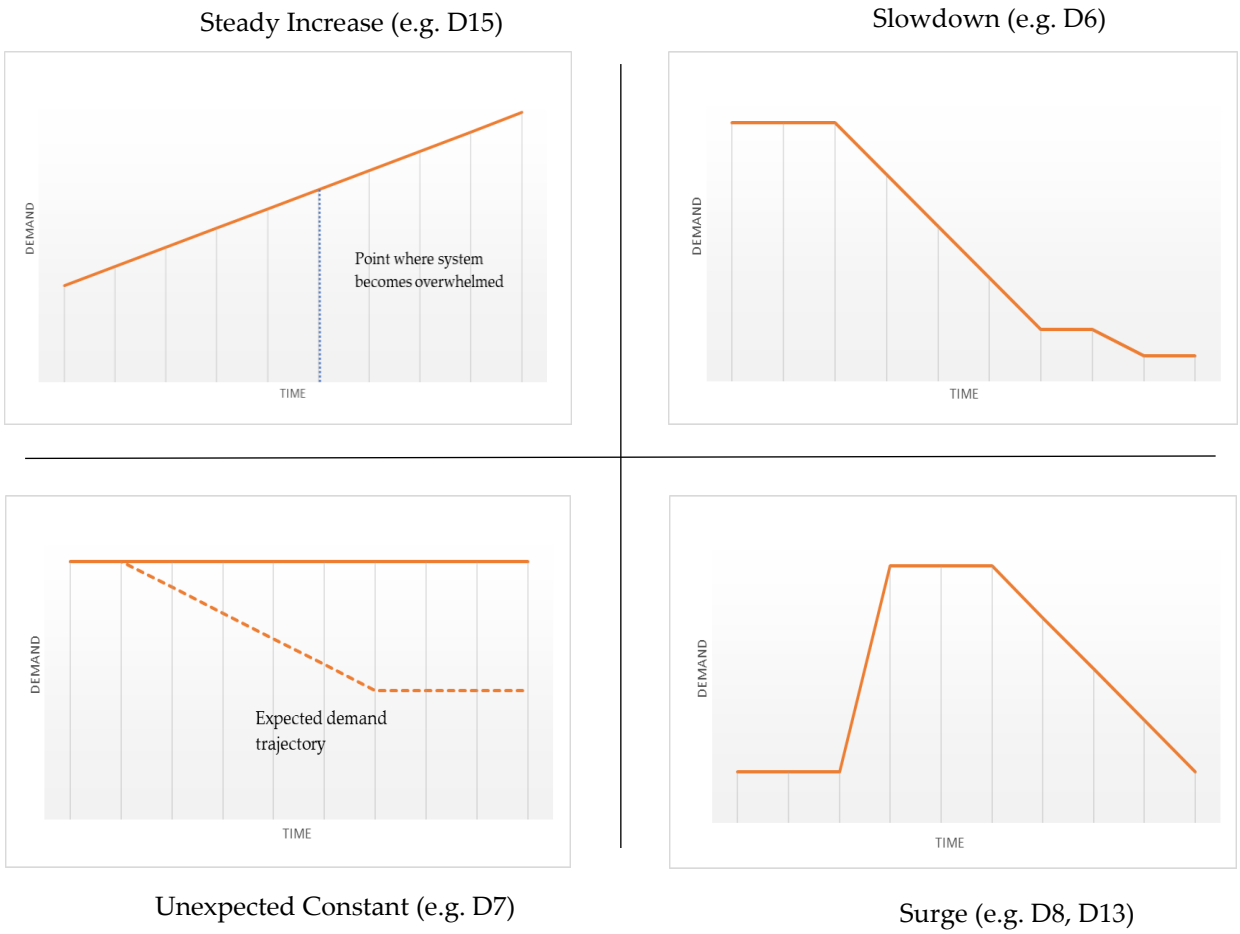

Figure 5.2 Demand Based Disruption Patterns

5.3.2 Supply-Side Disruptions

Supply-side disruptions lead to an inability to satisfy demand due to issues that impact the ability of a system to import materials and/or information that is required to maintain adequate performance levels. Although the disruptions refer to the inability to import materials (thus suggesting they only arise from exogenous sources), they can also emerge from internal system dynamics. A common example of this is an organisation that has an unexpected staff shortage. Similarly, the above behaviours of demand-based disruptions can be recontextualised within supply side.

Therefore, the driving factor for the disruption is not the consumption of goods caused by demand behaviours. Rather, the disruption manifests itself as an inability to meet demand rates or system goals due to supply input issues. Within some scenarios (such as disasters), the system will face a combination of both supply-side and demand-based disruptions (Mackay et al. 2019).

5.3.3 Forced Adaptation

Although systems undergo change—and may shift basins of attraction as a response to the disruption—it can be argued that the shift towards different basins of attraction may constitute a disruption by itself.. As discussed within the previous chapter these often took the form of organisational takeovers, whereby individuals needed to adapt towards new procedures, or environmental factors (i.e. government legislation) that required the system to change existing mechanisms to accommodate for these exogenous requirements.

The factors that influence system restructuring vary. As discussed in Chapter 2 system adaption can occur as a result of a catastrophic event (Scheffer et al. 2001), however system restructuring can be a purposeful endeavour, such as an organisation undertaking a merger or acquisition.

5.3.4 Goal-based Disruptions

The last category of disruptions proposed are those of goal-based disruptions. Although the above three disruption types (demand, supply and restructuring) can be argued to impact the ability to meet overall system goals, the goal-based

disruptions are more specific to particular tasks or 'jobs' at hand. These disruptions are based upon the idea of 'jobs' discussed by Christensen et al. (2007); a particular customer need or requirement within a given situation. Therefore, as the previous disruptions are often system-wide, these disruptions focus on individual tasks and projects.

By nature, these types of disruptions are contextual. The *types* of goals vary between systems and subsystem units; such as individuals within organisations, who are going to have a wide variety of different goals they need to meet.

5.3.5 Disruption Profile Framework

By proposing a disruption profile framework, it is argued that systems can appraise their vulnerability towards particular disruptions by delineating overall vulnerabilities and threats into disruption types, emergent from sources both endogenous and exogenous. Figure 5.3 proposes this framework, outlining both the exogenous and endogenous forces that influence the various disruption types which, in turn, determine the overall disruption profile.

Although Figure 5.3 suggests that the various endogenous and exogenous forces that influence the disruption types may lead to several disruption archetypes, the existence and characteristics of these archetypes fall outside the scope of this thesis and guides future research areas. The utility of the above model is that it

provides a holistic perspective on the various endogenous and exogenous forces that may impact the performance of a system across four areas.

5.4 Choice Types

As discussed previously in the thesis, the conceptual framework proposed choices as

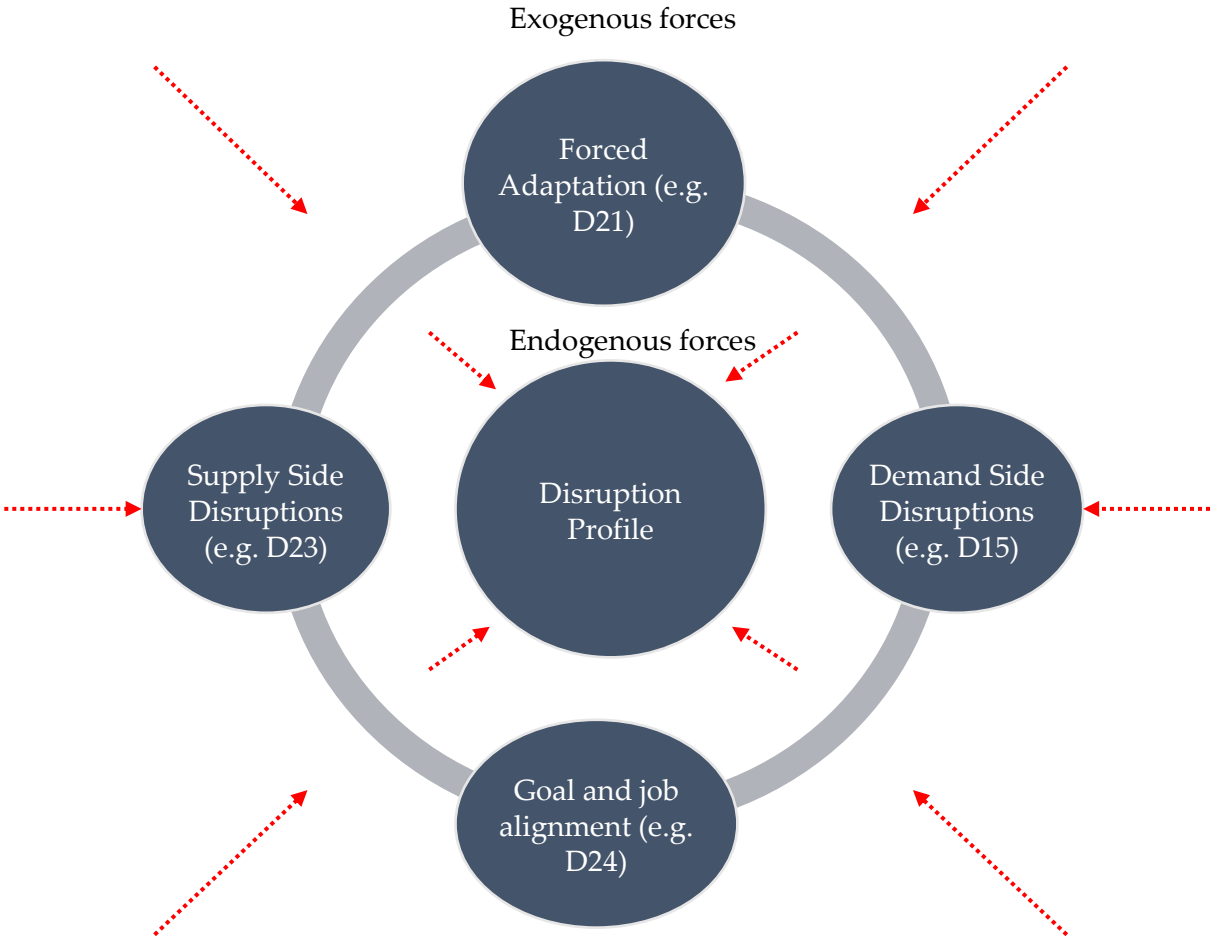

Figure 5.3 Disruption Profile Framework

being temporal (proactive/reactive) and strategy (redundancy or flexibility). As these two dichotomies are utilised heavily within the operations management and supply chain literature (as discussed in Chapter 2), a contribution of the thesis was linking these to decision-making rationale (namely the threat and coping appraisals explained by Protection Motivation Theory). Although the individual choices could

be defined across these dimensions, there were more complex interactions at play due to the systemic factors that influence both agency and choice utility

Namely, there was a degree of rapidity associated with choice; the extent to which individuals acted 'fast' or 'slow', borrowing from the intuition/reasoning decision-making literature discussed in Chapter 2. As discussed in the previous chapter, fast actions can lead to both optimal and suboptimal outcomes, subject mainly to individual appraisals of the threat and the impact of their actions. Therefore, it is argued that the rapidity of a choice—the degree to which it can be classified as fast or slow—serves as an additional dimension of choice alongside the temporal scope and strategy.

5.4.1 Model of Disruption Mitigation Choices

Figure 5.4 presents a model of disruption mitigation choices based upon the choice types discussed in the previous section. As a cube model serves as one type of typology (Collier et al. 2012), it is argued that Figure 5.4 serves as a theoretical framework of disruption mitigation choices to serve as an extension of extant decision-models within the literature. The phrase mitigation is not designed to reflect a temporal scope, but rather the model argues that choices which are designed to bring a system back into an ordered equilibrium post-disruption can be classified across to the dimensions reflected in the model. The model does not

suggest an 'ideal' type of choice, as contextual factors (e.g. individual framing) have been demonstrated to have a substantial influence on the utility of choices.

5.5 System Behavioural Types

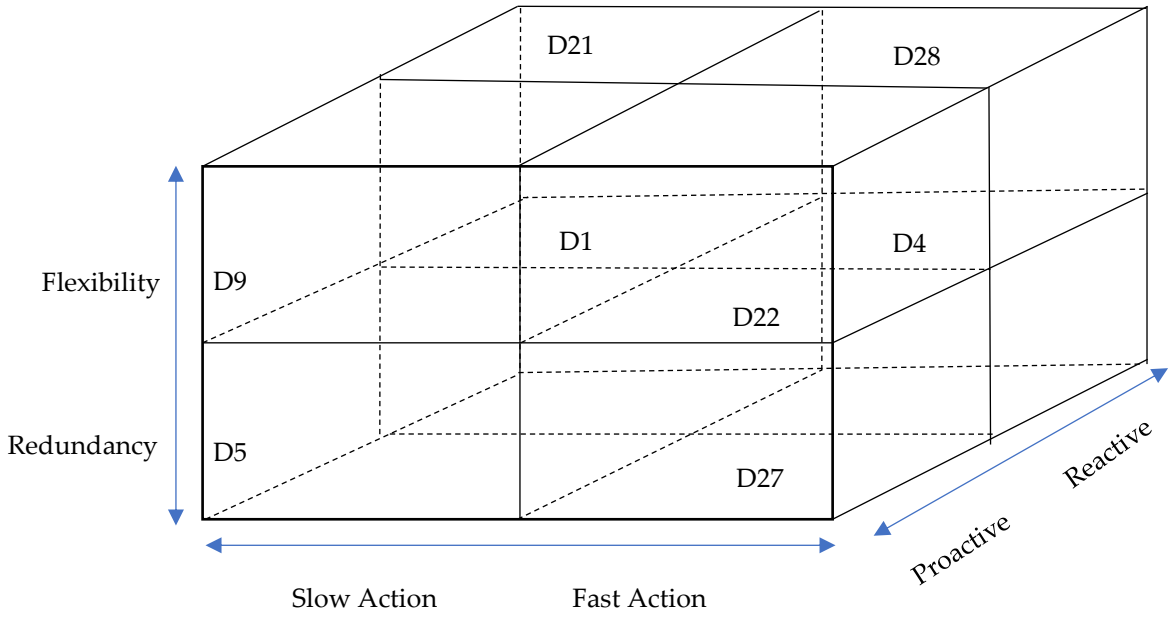

Figure 5.4 Model of Disruption Mitigation Choices

As discussed in the previous chapter, the idea of transient response (i.e. when a disruption begins) was difficult to ascertain in scenarios when the disruption began outside the focal system. Unlike the temporal scope of choice—which is determined by an individual appraisal of a disruption occurring—the transient response is an objective determination. It can therefore be argued that issues surrounding its identification was due to the subjective nature of the research, and thus perhaps renders itself useful towards future research endeavours.

However, as discussed in the previous chapter there were several behaviour types that emerged from the interviews. The following section proposes these

behaviours; responsive returns, disruption dissipation and system component/goal failures. Similar towards the discussion of disruption types, due to the predominance of framing influencing how individuals experienced disruptions, the thesis acknowledges the potential existence of latent behaviour types.

5.5.1 Responsive Return

Responsive returns were the most common behavioural type; when the interaction between choice and the system lead to the system returning to its equilibrium. In other words, the system possesses adequate levels of resilience to return to an acceptable level of performance. Although the thesis did not explore the causal link between the choice and the outcome, it can be inferred from the interviews that the individuals believed their choice (or the choices of others within the system) were the reason the system was able to return to acceptable performance. Within these types of behaviour the system resilience determines the speed in which the system is able to return back to an acceptable level of performance.

5.5.2 Disruption Dissipation

Particularly common within demand-based disruptions, at times the system would return to normal primarily due to the levels of demand dissipating over-time. A few conclusions can be derived from this.

Firstly, disruptions dissipating overtime suggest that the choice does not impact the cause of the disruption—in other words, the rate of demand—but rather allows (if the choice was appropriate) the system to maintain adequate performance

during the demand-behavioural disruption. However, the choice acts as a mechanism to ensure the system does not fall into a state of chaos of which it is unable to return.

Therefore, this type of behaviour is restricted to systems whereby the magnitude of the disruption can be measured as a rate (i.e. demand rates). For disruptions of other types, such as goal-based disruptions, the system behaviour becomes more outcome driven; namely, whether the system was still able to meet goals despite the occurrence of the disruption.

As framing plays an important role in the positioning of individuals and disruptions within peripheral systems, a disruption within one part may dissipate over time but still exist in another part of the system. Namely the source of a disruption may taper, but the effects of the disruption can still be felt in other parts. A contextual example of this are disasters, whereby the initial disruption (e.g. an earthquake) may dissipate within a small timeframe, but the impact of the disruption takes a longer time to return to pre-disruption stability (Mackay et al. 2019).

5.5.3 System Component and Goal Failure

The least desirable outcome for any system is that of failure. As discussed in the previous chapter this manifested across two states: the failure to reach a certain goal (i.e. for goal-based disruptions) or the acute failure (and thus perishing) of a system and/or subsystem component. Thus depending on the context the costs of system

failure can be low (Holling 2001) as the robustness and resilience can absorb the impact of the disruption.

Goal-based system failure refers to the inability to reach a goal—often associated with a project or particular job—within either a specific timeframe or to the standard required (either by individuals in the system or exogenous forces such as clients). Thus, goal-based failure is subjective; although an individual is unable to reach a certain goal, this may not be viewed as a failure within other system components or the wider suprasystem.

Extreme magnitude disruptions—such as disasters—are often discussed as the result of a system being unable to emerge from chaos without exogenous assistance (Mackay et al. 2019). This idea itself assumes overall system failure, whereby there may be peripheral sub and suprasystems that are still operating at acceptable performance levels and thus able to (1) absorb the impact of a disaster to avoid chaos impacting more systems, and (2) provide exogenous assistance to the focal system to assist in its recovery.

5.6 Disruptions, Order and Chaos

Systems will operate within an expected equilibrium defined by the goals of the systems. This equilibrium can be expressed as a state of order or the stable basin of attraction. Accordingly, if a system can maintain performance (e.g. a goal-seeking system that consistently meets goals), it will drift continuously further into this stability basin. Conversely, general stochasticity and disruptions seek to shift the

system away from its stable equilibrium into a chaotic basin. As disruptions can be manifested as an arguably infinite number of forms collated into several dimensions (discussed in Figure 5.3), systems are constantly at risk of shifting into a state of chaos.

Thus, depending on the magnitude of a disruption a system can shift into a state of chaos; whereby it is unable to return to this expected equilibrium without a course of action imposed by individuals with agency. Within an automated system (i.e. not a social system), non-human agents assume this role.

The shift between basins of order and stability can be expressed as either a subjective or objective phenomenon. The manifestation of this disruption can be expressed as either an established phenomenon (e.g. an earthquake that measures a defined magnitude, or a disruption with a measurable surge in demand) or a lived experience (i.e. perceptions of the individuals impacted by the disruption).

There are two potential arguments to this; that the chaotic behaviour of a system is either subjective or objective. Several cases support both sides of these arguments; individuals could act calmly and methodically towards a disruption, but to other peripheral systems or subsystem (e.g. other individuals) the disruption may appear disordered.

The framing of this question around social systems—where individual agents act with varying degrees of rationality and information—may provide unique

answers not attainable from traditional objective methods of understanding chaotic behaviour.

The implications of this idea are that conflicting interpretations of whether a disruption is causing chaotic behaviour can impact the performance of an overarching subsystem. For example within systems that operate under significant information constraints—such as disasters (Day et al. 2009)—misalignment within disruption magnitude interpretation may lead to suboptimal decision-making as subsystem needs are not known or understood by peripheral decision-makers.

The models proposed within the chapter seek to provide guidance in ascertaining a holistic perspective on individual decision-making within systems facing disruptions. The argument guiding this is that greater understanding of the triadic behaviours (individual, system, disruption) can lead to more efficient decision-making processes. In another paper (Mackay et al. 2019), the author discusses the benefit of a more holistic understanding of disasters as a tool towards better informing humanitarian relief supply-chain design. A similar sentiment is expressed towards the models proposed within this chapter.

5.7 Conclusion

The chapter has sought to bring together the major points of the thesis—ranging from both the literature review chapters and the results derived from the semi-structured interviews—into various points of discussion outlining the main theoretical conclusions derived from the thesis. The first section of the chapter

sought to revisit the research questions and outlined how the interviews provide guidance towards understanding the individual and systemic factors that influence protective choice against disruptions, and the complexity of the relationship between these choice formulations and the system response.

. The bulk of the discussion that dominated the second half of the chapter proposed a series of models or types reflecting the main stages derived from the initial conceptual framework proposed in Chapter 3. First, the importance of framing within systems proposes that an open system can be expressed as possessing holistic interactions with both direct and indirect peripheral systems. In turn, similar interactions will occur within peripheral systems.

Secondly, the disruption types arose from four main areas; demand behaviours (consisting of demand surges, constant demand, steady increase demand and demand slowdown), supply issues, forced adaptation and goal-based disruptions. These in turn informed the disruption profile framework, which ultimately seeks to provide a holistic overview of the nature of threats faced by any given open system.

The next part of the chapter proposed the model of disruption mitigation choices, expanding on the choice classification dimensions discussed in the conceptual model—temporal (proactive/reactive), redundancy/flexibility—by proposing a cube model inclusive of both these and the rapidity an action is undertaken (slow/fast). Although the resultant model proposes these as binaries

(and uses cases from the interviews as cell types), this is primarily done for simplicity as they are expected to be continuums. Following on from this, the chapter discusses the various system behavioural types that were found within the interviews. Although responsive returns were commonly found, other interesting behaviours were uncovered, namely the disruption dissipation and the system component and goal failure. The chapter finishes with a discussion surrounding disruptions and chaos discussed in Chapter 2. Namely, systems will aim to consistently be attracted to a state of order, whereby disruptions can temporary shift a system into a state of chaos. For social systems, individual decision-making serves as a mechanism deployed to shift the system back towards the state of order.

Chapter 6 Conclusion

The thesis has sought out to explore the behaviour of systems under uncertainty from the lens of individual decision-making within systems facing disruptions. Acknowledging the complexity of social systems, the thesis has sought to contribute to current ongoing academic debates surrounding how individuals make choices under risk, and the utility of particular risk strategies and their interaction with the systems individuals operate in. This chapter synthesises the main contributions of the thesis, acknowledging any possible limitations as the foundation for future research.

The thesis also contributes several contributions across theoretical, methodological and practical benefits. These offer insight into future research areas that will serve to gather further understanding of the complex relationships between individuals and the systems they operate in. The chapter finishes with various remarks reflecting on the overall thesis.

6.1 Contributions

The following section outlines the three major areas of contribution within the thesis. Although intertwining at times, these are delineated into three sections. The theoretical contributions are centred on additions to concurrent discussions within the literature surrounding systems theories, PMT and risk-based decision-making. The methodological contributions are centred on the use of semi-structured

interviews to draw inferences within traditionally positivist discussions of individual decision-making, and the utility of eliciting in-depth experiences towards the research questions. The final series of contributions concern the practical nature of the major theoretical discussions outlined in the previous chapter.

6.1.1 Theoretical Contributions

The main theoretical contributions are centred on contributions towards the extant literature that can be split more definitively across the various areas espoused within the previous chapters and based on the model proposed by Scheibe and Blackhurst (2017); namely the system, disruption and decision-maker.

In terms of the disruption, the thesis proposed a disruption profile framework that espouses a holistic overview of endogenous and exogenous disruption sources. The basis of this argument is that disruptions are complex and can arise from multiple areas depending upon the system contextualisation and framing. Thus, practises of listing risks will only capture disruptions that are known and measurable.

For the system, the thesis argued that systems will display several behavioural types based upon the strategic and operational resilience and robustness. Disruptions temporarily shift the system into a state of chaos; for some systems this is a common occurrence, for others this is not a natural equilibrium.

For the decision-maker, the thesis explored how individual framing of their positioning within a system, in culmination of the roles of sub and suprasystems,

influences the appraisals of efficacy and agency. In terms of the utility of choice, the thesis provided a theoretical contribution towards extant discussions surrounding redundancy and flexibility by arguing that choice is a complex interaction between both known and latent forces and can be distilled across temporal (i.e. proactive/reactive), redundancy/flexibility and rapidity (i.e. fast/slow) dimensions.

6.1.2 Methodological Contributions

From an ontological perspective, the thesis has uncovered several insights into how individuals construct disruptions based on the triadic intersection between individuals, disruptions and systems. The importance of this is its ability to demonstrate the potential variance in perspectives and experiences of similarly grouped disruptions, and how these variances can impact both the perceptions of events and the ability to act.

The thesis takes novel approach to exploring risk behaviours by moving away from the quantitative methods that dominate much of the extant theories on decision-making under uncertainty. By employing semi-structured interviews—based on the critical incident technique and guided by the interviewee—allowed for unique insights to be generated that may not have been obtained from quantitative methods. Although quantitative methods would have allowed for process and variance perspectives on theory to be derived, it is believed that they would have been limited in their explanations of system interactions. Therefore, the thesis has demonstrated the usefulness of qualitative methods as a tool for eliciting themes for

theoretical development, whilst acknowledging the power of other methods for future research trajectories.

6.1.3 Practitioner Implications

Rather than seeking to provide a definitive answer as to the 'ideal' strategy against a certain risk, the thesis has sought to provide useful tools to evaluate decision-making under uncertainty, with the aim of enhancing decision-maker capability to guide system performance. The ability of the findings to be universally applicable allows for them to be used within any open system subject to human interaction. As discussed within the first chapter, the various tools espoused by the thesis can be used to help explain the triadic reaction between individuals, systems and disruptions and accordingly be used to inform more effective decision-making.

This point is expressed through the models proposed within the discussion chapter. These models—namely the system framing model, the disruption profile framework and the model of disruption mitigation choices—can be used as useful tools for practitioners to gain a more holistic understanding of disruption—and their own—behaviours. The system framing model allows practitioners to gain a more holistic understanding of the relationships they have with both direct and indirect systems (both subsystems and suprasystems).

The disruption profile framework can be used as a tool to understand the complexity and vulnerability of systems towards various disruption types, and their extant capabilities to deal with known disruptions. Secondly the model of disruption

mitigation choices allows for a proactive appraisal of existing capabilities to be undertaken.

6.2 Limitations

Although the semi-structured approach aims to explore individual perceptions, the study uses the theoretical framework to explain individual and system behaviours. Grothmann and Reusswig (2006) acknowledges a similar limitation, arguing that although this approach can be justified if the perceptions remained static, behavioural feedbacks may impact this ascertain. Furthermore, qualitative research—by nature—runs the risk of being driven by subjective determination than objective procedures that would dominate a quantitative approach. Although the two research paradigms offer separate values towards academic discourse, the purely qualitative nature of the thesis leaves the results subject to potential challenges from quantitative approaches. Similarly, the contextualisation of definitions within section 3.4.1 narrows the scope of the research towards the rigid definitions informed by the literature. The author views these not necessarily as limitations but as complementary potential future research areas.

As briefly discussed in Chapter 3, the lack of consensus surrounding data saturation lead to a protocol being created for the purposes of the thesis that emphasised the 'richness' of data, and the point whereby no new interviews would generate new information or codes. As the thesis promotes conceptual and

theoretical development, it is important to acknowledge the perceived drawbacks of theorisation.

Furthermore, the thesis acknowledges the role of empirical validation within theory development. Therefore, although the models discussed within the previous chapter are emergent from empirical knowledge, further refinement is needed to establish their utility as theoretical stipulations, like the methodological limitations discussed above.

6.3 Future Research

As the research has been exploratory in nature, a core focus has been the identification of future research trajectories resultant from the interview process. The main points of discussion identified in Chapter 5 each serve as unique areas for future research projects.

First, the typology of choices proposed offers a path of additional empirical validation through other research methods. For example, testing the utility of the model by following popular quantitative research designs within the risk management literature may offer additional insights into the manifestation of the three dimensions as classification tools for choices. These may include popular methods within the extant risk literature such as surveys (Bubeck et al. 2012) in order to provide a quantitative analysis of the research. Furthermore, this may contribute to concurrent discussions various areas of the literature surrounding the power of risk perceptions in influencing choice, and the utility of redundancy and

flexibility strategies. Therefore the thesis provides a stepping stone for future research, for example two in-progress papers by the author exploring redundancy and flexibility from both a conceptual and empirical (through simulation modelling) perspective.

6.4 Concluding Remarks

As common with all research projects, aspects of the thesis have shaped and manifested themselves over time. However, one thing that has remained constant has been the wish to gain further understanding of the complexity surrounding decision-making within systems. There for wishing to gain understanding—rather than presuppose outcomes—the methodology and research design have purposely been exploratory.

Ultimately the thesis proposes that it is impossible to delineate the complex components of a system into independent variables; although parts of the study can be replicated in experimental designs, there exists a degree of holistic and chaotic behaviour between system components that may not be adequately captured in such designs.

One of the main points of interest through the thesis was how often disruptions emerged from routine events. It is entirely probable that social systems are inherently chaotic, and often drift between various basins of attractions of order and disorder. Although a shift of system behaviour into chaotic oscillations does not guarantee failure—and may indeed lead to new positive states of existence—the

perpetual existence of disruptions suggests that need for individuals to be simultaneously proactively preparing, and reactive acting, in order to deal with chaos and manage system viability.

> "Living systems are never in equilibrium. They are inherently unstable. They may seem stable, but they're not. Everything is moving and changing. In a sense, everything is on the edge of collapse." (Crichton 1990, p. 246)

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Appendix A: Interview Questions

Below are the questions used within the interview. As the interviews were semi-structured, questions were adapted to reflect contextual observations. These questions served as a mechanism to ensure that the major themes identified within the conceptual framework were obtained from the interviews. Although several interviews provided system-centric perspectives on disruptions, these questions were still used to guide the research.

Interview Questions

(1) Please provide a description of the system and its overall goals (i.e. if business; type of business, its general aims and how these impact day-to-day operations).

(2) Prior to the disruption occurring;

(2a) Did you expect such an event to occur? If so;

(2b) Why did you perceive that event as likely to occur?

(3b) If not, when was the disruption realised?

(3) Regardless if it was perceived beforehand or detected after its occurrence, what impact did you believe the event would have?

(4) Why was protective action needed to respond to that disruption?

(4a) Why did you choose to do (or not do) that particular action?

(4b) What other choices could have been made?

(5) If you did nothing, what did you believe the impact to be on your business operations?

(6) Once the protective action was enacted, what was the impact of the disruption on the system?

(6b) Was the action adequate enough to assist the system to recover post-disruption? If not:

(6a) Did you require external assistance to recover from that event? If so, in what form? OR

(6b) What other choices needed to be made to ensure system viability?